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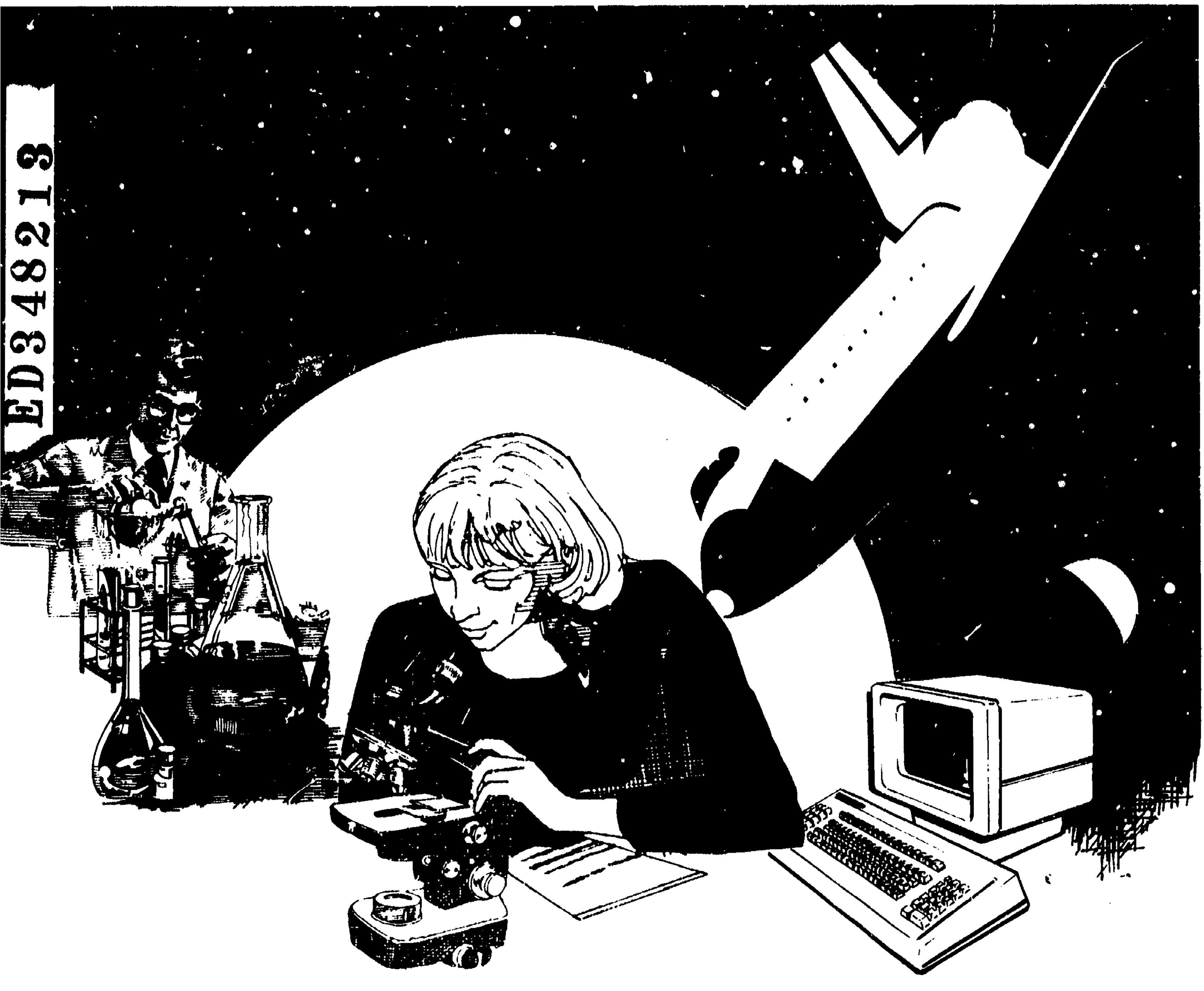
ABSTRACT

The purpose of this guide is to aid K-12 curriculum planners in the development and implementation of well-defined programs of study in science suitable for their local school districts. Among the national trends reflected in this guide are the interdisciplinary approach; the use of performance-based student assessments; the utilization of diverse philanthropic, commercial, and scientific organizations to provide for academic enrichment; and the expanded use of appropriate educational technologies both in science and across other domains. This guide has the following contents, by chapter: (1) rationale, purpose, and the 14 steps in the suggested process; (2) philosophy, goals, and objectives of a typical program with examples of each category for elementary, middle, and secondary schools; (3) importance of up-to-date programs, suggested time allotments, and patterns and electives within a science program; (4) specific objectives within life science, physical science, and earth science for the attitudes, skills, and understanding of students completing grades 3, 6, 8, and 12; (5) requirements and materials for students with special needs; (6) planning essential for self-contained classrooms, science centers, and laboratories; (7) school safety programs and teacher responsibilities; (8) laboratory equipment, computer hardware and software, other interactive devices, and textbooks; (9) community interaction through field trips, consultants, internships, and clubs; (10) evaluation, assessment, and test instruments; (11) sources for the professional inservice development of teachers; and (12) appendices that include the following: statewide educational goals; pertinent legislation; examples of instructional units; the domains, skills, and concepts for Connecticut secondary schools science subjects; suggested criteria for textbook selection; laboratory safety rules form; instate field trip sites; state and national events of interest; state policy on academic freedom and public education; and a list of Connecticut's regional educational service centers. Lists of references and resources are furnished with each chapter, as appropriate. (JJK)



A GUIDE TO CURRICULUM DEVELOPMENT

SCIENCE

STATE OF CONNECTICUT BOARD OF EDUCATION • 1991

A GUIDE TO CURRICULUM DEVELOPMENT IN SCIENCE

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Malcolm Cheney, East Hartford Public Schools
Bette Del Giorno, Fairfield Public Schools
Mary Dooley, Hamden High School
Linda Froschauer, Greenwich Public Schools
Delilah Gomes, West Haven High School
Robert Hartman, State Department of Environmental Protection
Barbara F. Kmetz, Trumbull Public Schools
Donald P. LaSalle, Talcott Mountain Science Center
David Lopath, New Britain Public Schools
Richard Mace, Bridgeport Public Schools
Robert A. Rosenbaum, Wesleyan University
George Wisner, United Technologies Corp.
Thomas Dudeck, United Illuminating Co.
Frank Salamon, State Department of Higher Education
Ralph Yulo, Eastern Connecticut State University

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Sigmund Abeles
Science Consultant

FOREWORD

The State Board of Education's most fundamental commitment is to educational equity and excellence for all Connecticut students. The depth and richness of that commitment is thoughtfully, thoroughly and forcefully expressed in *Challenge for Excellence: Connecticut's Comprehensive Plan for Elementary, Secondary, Vocational, Career and Adult Education 1991-1995*. This series of curriculum guides, developed for the 1990s, represents an important element in the Board's efforts to achieve Goal VI of its Comprehensive Plan: To Improve the Quality of Instruction and Curriculum.

These books also are published to carry out the State Board's statutory responsibility to "prepare such courses of study and publish such curriculum guides . . . as it determines necessary to assist school districts to carry out the duties prescribed by law." The letter of the law which requires the Board to provide these materials is clear, and clearly important. More important, however, is the manner in which the Board embraces the task of meeting the spirit of the law.

The Statewide Educational Goals for Students 1991-1995 (part of the Comprehensive Plan adopted by the State Board in April 1990) and *Connecticut's Common Core of Learning* (adopted in January 1987) together are the heart and soul of the achievement we envision for all Connecticut students. This vision can only become reality, however, at the district level through the creativity, talents and special understanding that local education professionals and citizens bring to the K-12 curriculum planning process. These curriculum guides are specifically designed to help districts develop state-of-the-art learning programs and opportunities in each of the 11 mandated curriculum areas: the arts; career education; consumer education; foreign language; health and safety; language arts; mathematics; physical education; science; social studies; and vocational education.

In these guides we have endeavored to present meaningful and up-to-date ideas consistent with the State Board's goals for public education. Central to this effort are the convictions that (1) all children can learn and are entitled to an appropriate education; (2) diversity is enriching to school systems and all students benefit from the opportunities that diversity affords; (3) no single method of instruction is adequate to meet the educational needs of all children; (4) schools share the responsibility to maximize the comprehensive development of students; (5) mastery of knowledge and the ability to manipulate ideas are essential to being productive citizens; and (6) schools are but one vehicle through which education can be fostered — the vital role families play in supporting student learning must be recognized and families and the public schools must cooperate effectively to maximize student achievement.

The Statewide Educational Goals for Students, *Connecticut's Common Core of Learning* and these curriculum guides describe what can and should happen in quality K-12 educational settings. This series seeks to firmly establish the principle that the individual student is the beneficiary of these curriculums. The State Board of Education's mission is to educate students to think, explore and apply a variety of knowledge in ways that reward them and that contribute to growth in our society.

The guides have been developed under the direction of subject-area specialists in the State Department of Education, with the assistance of advisory committee members chosen from schools, universities and, in some cases, other agencies or community groups. These individuals have brought to the task a rich variety of experience and a shared commitment to the education of Connecticut students. Procedures suggested in these guides, while strongly recommended, are optional; the content represents expert professional opinion rather than state requirements. (In cases where state statutes prescribe certain content, the appropriate statute is cited.)

It is our hope that these guides will be used as resources in an ongoing curriculum planning process that has as its focus the lifelong achievement and well-being of all Connecticut students.

Gerald N. Tirozzi

Gerald N. Tirozzi
Commissioner of Education

PREFACE

The purpose of *A Guide to Curriculum Development in Science* is to assist curriculum planners in local school districts as they develop and implement their own programs of study in science. Each science curriculum must provide students with an equal opportunity to receive a planned, ongoing and systematic program of suitable educational experiences.

This guide incorporates a number of changes reflecting developments that have taken place in the field of science education since the first Guide to Curriculum Development in Science was published some years ago. Notable among these are the increased emphasis on student participation in investigation in science and the uses of technology in the science classroom and laboratory.

Several national trends also are reflected in this guide. One is a concerted look at the scope and sequence of the science program. Another is the use of performance assessments for the evaluation of student accomplishment. A third is the use of collaborative efforts involving science museums, science centers and various businesses and industries to provide enriched activities for students and teachers. A fourth is the use of educational technologies that expand the types of learning activities taking place in science and those that link science with other disciplines. These trends are evolving and will continue to do so over the years ahead.

This guide should provide a useful document for the development of a local curriculum guide in science. It contains suggestions for a statement of philosophy for the science program. It provides recommendations for the setting of goals and objectives, the instructional program, time allocations, physical facilities, safety considerations and the use of community resources. The guide also contains suggestions for working with students who have special needs. Finally, it offers ideas for the professional development of faculty and staff. It is important that each local curriculum development committee make itself fully aware of what is taking place in other localities and at the state and national levels as it develops its own science curriculum.

Students moving through our school systems are facing an increasingly complex and technologically oriented world. They need to be well grounded in the sciences in order to be prepared, knowledgeable and skilled citizens who will be productive and self-fulfilled. The schools play a critical role in this process. The science curriculum is an important means to assist students in the discovery of their natural environments and their roles in it. If this guide is useful in helping them to achieve this knowledge and these skills and attitudes toward themselves and their surroundings, then the goals of all those involved in the preparation of this document will have been realized.

DEVELOPING A SCIENCE GUIDE 1

"Most of the fundamental ideas of science are essentially simple, and may, as a rule, be expressed in a language comprehensible to everyone."
– Albert Einstein

Intent of the Guide
Uses of the Guide
Steps in the Development Process
Local Curriculum Guides

We are entering a new era. The past decade has seen tremendous growth in the fields of science and technology. Our entrance into the age of "information and technology" has brought us into closer contact with people from all parts of the world; it has changed our ways of doing business and our manufacturing techniques; it has altered the ways in which we spend our leisure time; it has opened avenues to the exploration of space; and it has allowed us to manifest our creative abilities in ways that heretofore were impossible.

The rapid changes taking place in science and technology also affect our system of education. They influence the curriculum from a content point of view and they are beginning to play a significant role in enhancing teaching methodologies. The effects of these fields must, therefore, be important considerations in the development of a curriculum guide in science.

Curriculum guides rarely find their way to the top of the best-seller lists. However, it is hoped that this document, and guides developed from it, will be different. This guide to curriculum development addresses a number of questions that school district administrators, supervisory personnel and teachers often ask about programs in science, such as:

- What is an appropriate scope and sequence of science offerings?
- What are the important concepts to be taught?
- With the current emphasis on accountability, on goal statements and student objectives, how can they be worked into the science program?
- How are textbooks and other instructional materials selected?
- What kinds of new educational technologies are available?
- What are important safety considerations for classrooms and laboratories?
- What scheduling and staffing patterns, times for laboratory activities and approaches to science instruction should be considered in developing and operating a science program?
- How is use made of community resources, professional organizations and sources of support for science programs?

The purpose of this guide is to suggest answers to these and related questions, so that when educators from a local school district sit down to plan their own science program, they will have guidelines and information with which to work. Beyond this, it is hoped this guide will provide assistance with recurring questions involving science programming, science classroom management and the role of science and technology in the school environment. If these purposes are served, then the creation of this document will have been justified.■

Intent of the Guide

This guide is intended primarily for curriculum planners, most of whom will be teachers. But the guide also is designed for a broader audience. Among those for whom the guide is intended are the following:

Members of local boards of education. The local board of education is responsible for approving the science curriculum as a part of its program of studies and for assuring that it is consistent with the best educational practices that can be brought to bear. The local board also is responsible for assuring adherence to state and federal guidelines. This guide provides an overview of what is involved in developing a high-quality science curriculum for Grades K-12.

Administrators and supervisors. The administrators and supervisors in the local school district are responsible for providing overall guidance and supervision for curriculum development as well as assurance that the goals and objectives of the district are met. School administrators and supervisors are responsible for scheduling time, providing needed resources and assuring a proper sequence for the science program. They must be familiar with the many components of the program and the means by which they were developed.

Classroom teachers. Ultimately, and consistently, the responsibility for working with students and providing them with the content, skills and values inherent in the study of science falls to the classroom teacher. Curriculum guides can help to provide an overall K-12 context within which a teacher can view a specific course and present the conceptual framework for that course in relation to the offerings which precede and follow it.

While diversity of content and methods of presentation are cornerstones of educational programs in a democratic system, there are certain objectives which should be targeted in every science program. A curriculum guide can be useful to teachers by indicating what these objectives are and by providing suggestions for their achievement.

References to examples of state and local guides appear on page 5.■

Uses of the Guide

This guide can be used in three ways: (1) to assist in establishing goals and objectives for the science program; (2) to assist in developing procedures in such areas as the selection of content, evaluation of materials and facilities, methods for dealing with students with special needs and staff development for science teachers, and (3) for an ongoing science program, to suggest procedures for selecting new texts, methods of maintaining a safe environment in the laboratory, resources for acquiring student

evaluation instruments, ideas for new courses and the use of new educational technologies, and types of professional development activities for teachers.■

Steps in the Development Process

To be most productive, a procedure for the development of a local science curriculum will make use of a coordinated effort among community representatives, administrators and supervisors, and the practitioners – the teachers – to as great an extent as possible. A science program that has no investment from those who will use it offers little chance of success.

The following 14 steps are suggested for the development of a local science curriculum guide. They represent four phases of the process: (1) getting started (Steps 1 - 3); (2) developing the guide (Steps 4 - 8); (3) implementing the guide (Steps 9 -12); and (4) evaluation of the program (Steps 13 - 14).

Step 1. Organize a science curriculum development committee. Select representatives from various levels – elementary, middle/junior and senior high schools. Administrators also should be represented to keep them informed of the committee's questions regarding district policies and procedures which can influence the development of the program. Identify resource personnel from other appropriate subject matter areas, from the community – particularly in science-related enterprises – and from higher education. These people can be called upon to give advice and assistance as the project progresses.

Step 2. Assess the status of the present local science curriculum. Before moving into a new program in science, the present program should be studied. What are its weaknesses and its strengths? What materials are on hand? How do teachers feel about what they are doing? What problems are there? What is needed in the new program that can help address those problems? Much of this information can be provided by the individual teachers; much can be provided by the science curriculum development committee.

Step 3. Research other science programs. Contact other districts, the Connecticut State Department of Education and commercial vendors to determine what recent program developments have taken place and what new materials are available. Often a science program, or elements of it, have been adopted recently by a nearby district which may be willing to share its experiences. Staff of the State Department of Education can suggest school districts that are able and willing to provide this kind of assistance. In addition, Department staff are knowledgeable about many recent practices and developing trends on both the state and national levels.

Step 4. Developing the philosophy and goals for the science program. A program in science should have a basic philosophy as its foundation. There should be goals for the program which are consistent with that philosophy. Program and student objectives then follow from the philosophy and goals. This approach will let everyone know what is being attempted, why it is being attempted and what is expected of those who take part in it. Once the science curriculum committee has prepared its own philosophy and goals, other teachers, administrators, selected parents, students, board members and other citizens outside the school system might look at them and offer their reactions. This information should be reviewed by the science curriculum committee and used for possible revision. The development of philosophy, goals and program objectives is discussed in Chapter 2.

Step 5. Prepare a scope and sequence for the program. Science programs run from K through 12 and should be designed along those lines. Even if a specific component of the program, e.g., K-6, 7 and 8, is of interest at a particular time, there should be an overall scope and sequence available so that such revisions do not lead to duplication or omission. Suggestions for scope and sequence appear in Chapter 4.

Step 6. Prepare specific objectives for the science program. The objectives for each course at the high school can be developed by the teacher of that course in communication with the department head and other teaching faculty to assure articulation with the overall science program. The elementary school teachers might usefully break into groups for the primary (K-3) and intermediate (4-6) grades to deal with the science objectives at those levels. Objectives should be stated clearly and concisely. Examples of these appear in Chapter 4.

Step 7. Obtain reactions to the goals and objectives. The final step in putting together the scope and sequence with its goals and objectives should be to get reactions. The reactions should come from science teachers; from representatives of other subject matter areas such as mathematics, reading and social studies; from the administration and from interested community people. Special care should be taken to assure that the science program is articulated with the mathematics program so that students have the necessary mathematical skills when they are needed in the study of science. While it often is true that science teachers must teach some mathematical skills in a science context, efforts should be made to ascertain that the necessary mathematical operation or skill has been presented at a time appropriate for the teaching of the science concept.

Step 8. Assure the provision of resources for the program. The scope and sequence and the objectives for the program provide the structure for the acquisition of materials. Major attention should be given to facilities

(see Chapter 6) and to assuring a safe and comfortable environment for students (see Chapter 7). Instructional materials, such as print, nonprint and electronic materials (see Chapter 8), should be selected to be consistent with the philosophy, goals and objectives of the program. Professional development (see Chapter 11) is an important element in maintaining an active and vital science program.

Step 9. Develop a guide that assures the provision of supplies, materials and equipment. A hands-on, process-centered elementary or middle/junior high school program will require sufficient supplies and equipment for pupil use. High school laboratory courses likewise will require lab supplies and equipment for individual or team experimentation by pupils. These, in turn, necessitate safe and adequate storage facilities (see Chapter 6), safety equipment and furniture to ensure a safe and comfortable environment for all students (see Chapter 7). The design of the facility should be flexible and adaptable in order to accommodate a diversity of instructional practices such as individual, small and large group work, teacher and pupil demonstrations, project activities and independent study and research.

Step 10. Assure that the materials selected are consistent with the philosophy, goals and objectives of the program and meet the needs and abilities of the student population. These materials include textbooks, laboratory manuals, a variety of workbooks, supplemental and enrichment aids, reference materials for student research such as journals, periodicals, specialized texts and research briefs and newsletters. In addition, electronic materials, including films, filmstrips, videos, models, transparencies and the essential hardware – film, overhead and opaque projectors, audio- and videotape recorders, computers with software and hardware peripherals, and micro projectors – should be available. All materials should be examined to ensure that they are free of gender and cultural bias. They also should contain materials showing the contributions of different cultures in the development of science and technology.

Step 11. Prepare a plan for professional development. Researchers and practitioners agree that the key variable in the classroom is the teacher. To ensure that a new or modified philosophy, goals, objectives and updated content are fully utilized, teachers must not only be involved in their development, but have the time to acquire the instructional strategies to implement the program. One-shot workshops are inadequate for this purpose. Teachers require time to incorporate the new content, skills, processes and techniques for using new equipment or tools into their teaching repertoire. Opportunities to pilot the program, to assess the ongoing process with their colleagues and to exchange and share ideas should be provided. The expectation of gradual implementation should be clearly communicated. Teachers should be involved in preparing the professional development plan as well as assisting in the selection of topics, presenters and resources.

Step 12. Prepare a plan for implementing the program. When the preceding steps have been completed, a plan for putting the program into operation should be developed. The plan should delineate the procedures and activities required, the specific individuals or groups participating, a timetable designating dates of operation and completion and the individual or individuals responsible for each task. For example, when will materials arrive for distribution? What about acquisition of living things which must be on hand at a particular time? When will specific professional development activities be conducted? How and when will the evaluation be conducted? How will new teachers be oriented and prepared? To ensure smooth implementation, it is essential that one person, be it a supervisor or coordinator, is given the responsibility to direct the total program on a continuing basis.

Step 13. Evaluation of the new program. There are two major types of evaluation for the new program. The first involves the extent to which the students are able to meet the objectives of the program. Are the objectives appropriate? Are they at the right level? Should they be changed? This first type of evaluation is an important component of the second; that is, how effective is the program? Is it advancing achievement? Are students obtaining the knowledge and developing the expected skills? Suggestions for testing and evaluation for use with local science guides appear in Chapter 10.

Step 14. Establish a subcommittee which will continually monitor, fine-tune and, when necessary, revise the program. Content and skills are not static – certainly not in science. Daily changes in technology, new discoveries in knowledge and new instructional approaches make the science program a continually varying entity. It must be monitored so as to encourage the introduction of changes that mirror the times and best prepare students for the future.

Once the first blush of the new curriculum fades, unless some means are established to carry on this work, little may be done to revise it. Curriculum revision needs to be continual and every consideration should be given to keeping the curriculum tuned to what is taking place in scientific research and development. This may be accomplished by the committee, a subcommittee or an individual who is assigned this responsibility. Following the above steps can assist a local school district in developing its own science curriculum guide and in implementing an effective science program.■

Local Curriculum Guides

Most Connecticut school districts have developed a science curriculum guide. The following districts have indicated either through the Program Compliance Review process or through other communication with the Department of Education that they have a curriculum guide available.

Ansonia	Enfield	New Haven	Suffield
Avon	Fairfield	Newington	Thomaston
Bolton	Farmington	New London	Vernon
Branford	Glastonbury	North Haven	Vocational-Technical Schools
Bristol	Granby	Norwalk	Wallingford
Brooklyn	Greenwich	Plainfield	Waterbury
Cheshire	Guilford	Plainville	Waterford
Clinton	Hartford	Plymouth	Watertown
Danbury	Hebron	Portland	West Hartford
Darien	Killingly	Rocky Hill	West Haven
Deep River	Manchester	Somers	Weston
East Hampton	Mansfield	Southington	Westport
East Hartford	Meriden	South Windsor	Wilton
East Haven	Middletown	Southbury	Willimantic
East Lyme	New Britain	Stafford Springs	Windsor
East Windsor	New Canaan	Stamford	
Easton	New Fairfield		

Resources

Alaska Department of Education. *Science – Model Curriculum Guide.* Anchorage, AK, June 1984.

American Association for the Advancement of Science. *Project 2061: Science for All Americans.* Washington, DC: American Association for the Advancement of Science, 1989.

California State Department of Education. *Science Framework for California Public Schools,* Prepublication Draft. Sacramento, CA, November 1989.

Indiana Department of Public Instruction. *The Indiana School Science Curriculum Guide.* Indianapolis, IN, 1980.

Iowa Department of Public Instruction. *A Tool for Assessing and Revising the Science Curriculum.* Des Moines, IA, 1983.

South Dakota Department of Education and Cultural Affairs. *South Dakota Framework for Science Curriculum Development, Kindergarten - Twelve.* Pierre, SD, 1980.

West Virginia Department of Education. *Essentials for Science K-8.* Charleston, WV, 1978.

Wisconsin Department of Public Instruction. *A Guide to Curriculum Planning in Science.* Madison, WI, 1986.

Philosophy, Goals And Objectives 2

> *"Nothing ever becomes real until it is experienced – Even a proverb is no proverb to you until your Life has illustrated it."*
> – John Keats

Our increasing knowledge of the rapidly changing world in which we live, brought about in large measure through efforts in science and technology, makes it essential for all citizens to be literate in these fields. While not everyone is or should be a biologist, physicist, chemist or engineer, everyone needs to know something about the nature of science, how the laws of science work and what can and cannot happen scientifically.

Because there is so much misunderstanding about science, it is important to help students understand the nature and value of scientific theories. Scientific theories are general statements that explain and organize a large number of facts, generalizations or events. All scientific theories are tentative because science itself is a dynamic and creative enterprise. No scientific theory can be proven in any absolute or final way, but each theory can be used with more and more confidence every time new observations or experiments produce results that are consistent with predictions based on the theory. Some students may think theoretical ideas are not very practical; just the opposite is true. There is nothing more practical than a fruitful theory because it enables scientists to predict, explain and give structure to many previously unrelated facts, observations and ideas. Indeed, the formulation of valid general statements – scientific theories – which in succinct form reveal the relationships between objects and events, can be said to be the most important and fundamental goal of science.■

STRUCTURING A PHILOSOPHY

Schools play a vital role in fostering creative thought, in providing information and in developing student attitudes toward science and technology. They also help future voters learn how to make responsible choices regarding science and society. As such, the science program is an essential part of the total school program.

It is important that everyone in the school district – citizens, board members, administrators, teachers and students – knows the rationale for the science program: why the program exists, what it is trying to accomplish and how it will go about doing it. For example, will the program concentrate on the teaching of concepts, skills, facts, processes or some combination of these? Will the program be textbook oriented to the exclusion of laboratory experience? Will it be directed at the individual or at groups? Will it be inquiry oriented?

The philosophy should include:

- reasons for offering the program;
- general statements as to what the program will do; and
- general statements as to how the program will accomplish what it intends to do.■

Examples of Philosophies

The philosophies which follow have been extracted from selected curriculum guides in science or from the statements of professional science associations. Note that each philosophy addresses the three criteria mentioned. These examples can serve as models or as points of departure for composing a philosophy for the local curriculum guide in science.

The following example is drawn from a statement prepared by the American Association for the Advancement of Science (1989):

> The first task and central purpose of science education is to awaken in the child, whether or not [he or she] will become a professional scientist, a sense of joy, the excitement and the intellectual power of science. Education in science, like education in letters and the arts, will enlarge the child's appreciation of [her or his] world; it will also lead [him or her] to a better understanding of the range and limits of man's control over nature.
>
> Science is best taught as a procedure of inquiry. Just as reading is a fundamental instrument for exploring whatever may be written, so science is a fundamental instrument for exploring whatever may be tested by observation and experiment.
>
> Science is a body of facts, a collection of principles, and a set of machines for measurement; it is a structured and directed way of asking and answering questions.

The Iowa Department of Public Instruction (1980) has developed a philosophy of science education which includes the following statements:

> Science education is the link between science and society. Its ultimate goal is to DEVELOP SCIENTIFICALLY LITERATE CITIZENS who use and understand the impact, knowledge and processes of science.
>
> The study of science offers a KNOWLEDGE OF NATURAL PHENOMENA that uniquely rests upon the notion that humans can test and understand the orderly nature of the universe. Funda- ·ntal to this proposition is a need for

students to develop and apply the logical thought PROCESSES OF SCIENCE AS PART OF THEIR BASIC LEARNING. These processes are best developed through a well-articulated science program that includes experimentation and manipulation of materials.

Yet another statement of philosophy created by the Indiana Department of Public Instruction (1980) contains these passages:

> Science and technology affect nearly every aspect of our lives; thus, all participating citizens of a democracy need to be scientifically literate. All high school graduates need basic science competencies. A wise decision-making, problem-solving, scientifically literate citizenry is the expected end product of the science program. . . .
>
> Science is not just a body of facts, theories, and laws, but it is also a unique way of knowing – a way to generate knowledge. . . .
>
> The value of science education lies in its problem-solving inquiry methods. . . .
>
> Students must apply scientific knowledge, as well as knowledge from other disciplines, as they attempt to solve problems which are meaningful to them. . . . Teaching strategies [leading to decision making] give purpose, meaning, and motivation to learning. . . .

Another statement of philosophy, delineated by the Weston, CT, public schools (1985), proposes that:

> As we move into the 21st century, science and technology play an increasingly important role in all aspects of our society; therefore, it is imperative that our future decision makers develop a positive attitude toward solving problems through science education. This attitude fosters a curiosity to understand and appreciate the natural world as well as to comprehend the impact of science and technology on the individual, culture and society.
>
> Science is more than a body of facts, a set of principles, or a collection of sophisticated tools; it is a structured, active method of asking and answering questions. A basic knowledge of scientific principles is one component necessary to form the foundation for future endeavors in the area of science. Likewise, an understanding of the logical thought processes involved in science is essential for developing a framework to apply to future learning. Creating this foundation and framework involves a well-articulated and developmentally appropriate science program which stresses the inquiry method through laboratory experiences as well as printed materials. Our end result will create scientifically literate individuals who will effectively use their science education to make wise decisions and become responsible, problem-solving citizens.

Finally, this last example was written by a parent, a scientist and a member of the Connecticut Science Advisory Committee that developed Connecticut's first *Guide to Curriculum Development in Science* (1981):

> With the increasing role of technology in all elements of our society, it is important for everyone to have an understanding of the nature of science, how it works, and what it can and cannot do. The fundamental principles and methods of science form both a knowledge base for understanding and a framework for learning. In the science program, principles and methods of science will be developed through both textbooks and laboratory experiences by involving each student in the major areas of earth and space science, biological science, and physical science at increasing levels of sophistication through the grades.

The philosophy for the science program should set its direction and tone. The goals and objectives for the science program rest on this philosophy. They should be consistent with the philosophy of the program, while lending greater definition to what the program will provide.■

GOALS FOR A SCIENCE PROGRAM

Program goals fall between the philosophy and the statements of objectives which are used to detail student outcomes.

There is considerable controversy over the usefulness for instructional purposes of student objectives. Many teachers are sufficiently knowledgeable and are organized well enough to know in detail what they intend to teach and what they expect their students to learn and perform without referring to written objectives. The advantage of written statements of goals and student objectives is that they can be seen. This allows them to be discussed, analyzed, evaluated and, if necessary, revised. It allows everyone involved to know what is being attempted and what types of performance are expected.

Statements of goals are developed on the assumption that the philosophy of the science program has been accepted. The science program is acknowledged as an important component of the district's educational offerings and the general instructional approach to it is considered appropriate.

The goals are written to provide the framework for specific instructional objectives and activities. These goals indicate what the program hopes to accomplish. The following examples of goals for science teaching, extracted from various sources, can be useful in developing the local curriculum guide in science.■

Examples of Goals

The following examples of goals have been developed by professional associations or by state curriculum development committees. As was the case with the philosophies for science education, these goals can serve as models or as points of departure for the development of local goal statements.

The following four goals for a science program are taken from the *South Dakota Framework for Science Curriculum Development K-12* (1980) produced by the South Dakota Department of Education and Cultural Affairs.

- To develop those values and attitudes which underline the personal involvement of the individual with his or her environment and with mankind.
- To develop the rational thinking processes which underlie scientific modes of inquiry.
- To develop fundamental skills in the manipulation of materials and equipment; in the care and handling of living organisms; and in the collection, organization and communication of scientific information.
- To develop knowledge of process, facts, principles, generalizations and applications – the products of science – and to encourage their use in the interpretation of the natural environment.

As can be seen, these goals are more specific than are the philosophies. They add direction to the science program and open the way for yet more specific statements of outcomes to be obtained.

The National Science Teachers Association, in its position statement on *Science – Technology – Society: Science Education for the 1980s* (1982), proposed the following five fundamental goals:

- To develop scientific and technological process and inquiry skills.
- To provide scientific and technological knowledge.
- To use the skills and knowledge of science and technology as they apply to personal and social decisions.
- To enhance the development of attitudes, values, and appreciation of science and technology.
- To study the interactions among science – technology – society in the context of science-related societal issues.

Finally, from the Michigan Department of Education's *Minimal Performance Objectives for Science Education in Michigan* (1974) comes the following goal statement:

> Our goal of science education is to develop scientifically literate citizens with the necessary intellectual resources, values and attitudes and inquiry skills to promote the development of a [human] as a rational being.

The statements of goals also are referred to as "program objectives" or sometimes as "objectives." In general, the distinguishing feature between statements of goals or program objectives and the learner or performance objectives which appear in the next section is that goals are directed toward what the program should offer, while learner objectives are specific as to what the individual student is to do.■

OBJECTIVES FOR STUDENTS

Objectives for students often are referred to as learner or performance objectives. The identifying feature of this

group of statements is that they define what the student is supposed to do.

If a goal for the program in science is to "develop scientifically literate citizens," then what is it that the students must do to achieve that goal? If a goal of the program in science is to "develop an understanding of the interrelationship between matter and energy," then how must the student demonstrate that understanding?

Ideally, learner or performance objectives must be written to describe in specific terms the behavior to be exhibited by the student. Often, excessive specificity can be frightening. For example, "The student, given a battery holder, a bulb and one 10-inch length of conducting wire, will in five minutes and in two different configurations construct a circuit such that the bulb will light." Objectives can be less threatening if they are not overly specific and if the means for stating and evaluating them are left in great degree to teachers.

The student objectives that follow were selected as examples from a variety of disciplines for different levels of instruction.■

Primary Grades

The student should be able to:

- list those things soil must have to make plants grow well;
- describe how soil helps animals;
- describe and list those things that should be added to the class aquarium to keep the aquarium balanced;
- list at least three requirements for the growth of all green plants; and
- separate pictures of plants and animals into two groups.■

Middle School/Junior High

The student should be able to:

- prepare a demonstration to show that sound cannot go from one place to another without the presence of matter;
- identify the similarities of and differences between fog and clouds;
- demonstrate how to mount a slide on the stage of a microscope and how to focus the scope using different power objectives;
- order a group of stones from lightest to heaviest; and
- separate a collection of rocks into two different groups.■

High School

The student should be able to:

- compare, contrast and discuss food chains and webs;
- explain the relationship of temperature to the kinetic molecular theory;
- relate the flow of fluids to pressure;
- identify the basic metric (SI) units that are used for measuring length, weight, volume and temperature; and
- define an ecosystem and compare biotic and abiotic components of the system.

These objectives, while more specific than the statements of goals described in the previous section, still are less specific than the battery and bulb example at the beginning of this section. The examples given here and in Chapter 4 were developed for broad populations of students. It is intended that they provide direction for the content of the local curriculum guide, while still permitting the flexibility necessary for individual situations.■

RELATING PHILOSOPHY, GOALS AND OBJECTIVES

For practical purposes, it is essential that the relationships among philosophy, goals and objectives are clearly understood. These are not unrelated entities. The philosophy determines the goals which then are translated into specific objectives. A philosophy becomes real only when this relationship is accomplished.

Assume that a particular philosophy states that "The aim of science education for the rest of the century is to develop scientific and technological literacy for all citizens." This philosophy emphasizes a general knowledge of the science processes, applications and information that all students taking part in the science program should have. From this statement many goals may be derived. One such goal could be: "To use the processes and knowledge of science and technology to develop personal objectives." This goal then presents a number of specific objectives. For example:

- The student collects data about science careers to assist in choosing an occupation.
- The student identifies sources of environmental pollution and determines courses of action to control them.■

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SCIENCE CURRICULUM – K-12 3

> *"In completing one discovery we never fail to get an imperfect knowledge of others of which we could have no idea before, so that we cannot solve one doubt without creating several new ones."*
> -- Joseph Priestley

Importance of Up-To-Date Programs
The Elementary School Program
The Middle School/Junior High Program
The High School Program
Suggested Time Allotments
Patterns of Science Offerings
Electives in the Science Program
Special Programs
Themes in Science Programs

In recent years the science curriculum has been the focus of much discussion. Many innovative courses have been written for different levels of instruction. In these courses, the emphasis has been placed on the process of scientific inquiry and the development of concepts rather than the mere memorization of a body of facts. These innovative science courses or programs were laboratory oriented. Laboratory experiences can be undertaken either in the laboratory or in the field.

In general, the courses or programs in science fall into three broad categories:

Courses or programs developed on a national level. These programs or courses are developed through the auspices and funding of the National Science Foundation or similar organizations. They generally feature authorship by teams at writing conferences. Activities are pretested on a large scale and materials are designed for use by the students. Typical examples of these courses or programs are "Science – A Process Approach" (SAPA), the "Elementary Science Study" (ESS), the "Science Curriculum Improvement Study" (SCIS), the "Biological Sciences Curriculum Study" (BSCS) and "Chemistry in the Community" (ChemCom). After extensive development, pilot testing and evaluation, the materials produced may be placed in the hands of commercial publishers.

Courses or programs developed on a state and local level. Some of these programs are designed by individual district staffs to meet the needs of specific target populations or to fit the needs of the school system. For example, one district developed an English-as-a-second-language (ESL) biology course for Spanish-speaking high school students. Another developed a mathematics-for-science course for students who wanted to take advanced-level science courses but did not possess the mathematics background for these offerings. Still another developed a course on the geology of the local area. Many districts develop courses particularly suited to the needs of their students (see page 18 for a list of a number of these courses). Some school staffs have developed programs which emphasize hands-on science at the elementary level and the incorporation of the science, technology and society theme into their courses. Several cities and states, particularly those that have end-of-course tests or statewide testing programs, are very specific about the content of their courses. They develop syllabuses which they follow and then test.

Courses or programs developed by commercial publishers. This category includes science texts and other materials which are used with great frequency in the schools. Many of these texts have taken their lead from the nationally funded curriculums. Some feature a student-centered activity approach and many include materials designed for student use.■

Importance of Up-To-Date Programs

Experience has shown that students need an education in science which not only keeps them abreast of recent developments in this field but which also allows them to cope with the ever-changing requirements of a dynamic society. Modern science courses have real meaning only to the extent that they allow the students to function better in their present and future environments.

Modern science courses attempt to use materials which are appropriate to the child's developmental state and which include both process- and content-oriented materials. Because of the rapid changes in science and technology, it is essential that instructional materials and texts be recent and appropriate.■

The Elementary School Program

Science should be a vital part of the elementary school curriculum for every child. Skills that should be taught in an elementary science program include observation, measurement, classification, prediction, communication, interpretation of data, experimenting, recognizing and controlling variables, and formulation of hypotheses.

All elementary science programs should address the three major content areas: biological science, physical science and earth science. Elementary school curriculums may conveniently consist of separate short units that can be completed in one period of time.

According to developmental psychologist Jean Piaget, elementary school youngsters are at the stage in their growth when they can benefit most from experiences with concrete rather than abstract situations. Most students will learn ideas and concepts much more easily if they can begin with the concrete situations upon which generalizations may be developed. Therefore, units should include many hands-on discovery activities. A laboratory approach may stimulate a child to learn science concepts in which the child initially may not have an interest.

In the primary grades, science is an excellent tool to help develop a child's vocabulary and reading interests. For example, when one is teaching a unit on properties of matter, the words used to describe an object can be used as a vocabulary list. This list can be expanded gradually as the sophistication of the description increases. There are many excellent science trade books written for elementary school children which may capture their interest and which may help increase their desire to read.

Mathematics should be integrated with science whenever possible. Many opportunities to use math-

ematics occur in the areas of measuring, using numbers, experimenting, estimating and data collecting. For example, when one is measuring the growth of plants over a given time period, graphing should be introduced as a tool to record the results. Where appropriate, the mathematics and science lessons should be combined. Language arts skills can reinforce communication of results of experiments or other findings by writing reports or publishing a class newspaper. Map reading, a topic for study in the sciences, can be used to integrate study in the earth sciences with study in the social sciences. Reading skills can be used to conduct library research on a topic of interest. By integrating as many science subjects as possible with other areas of the curriculum, additional time will not be added to an already full school day, but more time for the teaching of science will be available.

At the elementary school level, where many teachers do not have a preparation in science, a professional development program is essential. Time must be devoted for professional developmental activities. These activities should be planned to assist teachers with both the content and pedagogy of science instruction and should be scheduled on a regular basis. The professional development or in-service planning committee of the school district should have representation from the science curriculum committee.

The presence of a science resource person in or available to the school on a regularly scheduled basis is highly recommended to aid teachers in the selection and implementation of science units. The science person serving as a teacher of teachers, a motivator and a consultant can make a significant difference in the quality of the science program.■

The Middle School/ Junior High Program

The middle school and junior high school traditionally have taken many different forms but usually include some combination of Grades 5 through 9. While experience has shown that there is distinctive need for this age/grade grouping, the middle school/junior high school program often is thought of in terms of a transition from the elementary school to the high school that incorporates programs from both. To be truly effective, the middle school/junior high school program must stand on its own merit, fulfilling the needs of early adolescent youngsters (10-15 years of age). The development of student self-awareness and an understanding of her or his place in our society should be part of the curriculum at this level.

Middle school programs in science should not be the upper end of an elementary science program followed by an unrelated beginning of a secondary science program. Care should be taken to assure that there is a logical sequence of concepts and processes moving from the lower to the higher middle school grades.

The middle school/junior high science program should be balanced in the areas of life, physical and earth-space science. Science members of the middle school/junior high staff should coordinate the program offerings with the assistance of representatives from the elementary and high school staffs.■

The High School Program

The organization of science into independent subjects such as earth science, biology, chemistry and physics has been standard at the high school level for many years. However, the content of science courses has undergone many changes. Originally, this content was designed to prepare students for college. Presently, the content of science courses is designed for a broad spectrum of students ranging from those going to college to those entering the work force directly after graduation.

The goal of a scientifically literate society is even more relevant today than it was in the past. Since everyone needs an understanding of science, today's high schools must undertake the fulfillment of a diversity of goals. One is the development of science skills and a knowledge of science for students not seriously interested in science as a career. Another is the opportunity for career development, both terminal and preparatory, in scientific and technical areas. Other goals include preparation for further academic pursuits and special activities for students of high interest or ability.

It should be remembered that secondary schools provide for the general education of students, and that in science all students should, at the minimum, be offered courses in earth-space science, biology, chemistry and physics.■

Suggested Time Allotments

The teaching of science is an essential component of the school program. Instructionally, there should be a heavy orientation toward student activity and laboratory experience. This type of instructional approach requires time and, as a result, there should be a local policy regarding time allocations for science instruction.

Based upon data from a National Science Foundation survey, as well as from a survey of timed allotted to secondary school science courses in Connecticut, the Science Advisory Committee recommends the following amount of time to be used for instruction in science:

Time Recommendations

Grades	Minutes Per Week
1-3	75 – 150+
4-5	135 – 200+
6-8	200 – 250+
9-12	280 – 315+

One of the most effective methods for strengthening the learning of science is the provision of adequate time for instruction. The time recommendations listed above should be considered carefully in organizing a program in science.

In Grades 1-5, science instruction often is integrated with instruction in other subjects such as mathematics, social studies and language arts.

In Grades 6-8, science most often is taught as a separate subject. The time recommendation at this level is based on a minimum of five 50-minute periods per week or their equivalent to allow for laboratory experience.

For the high school, seven or eight periods per week or a time equivalent to 280-315+ minutes per week is recommended. These figures are based upon seven or eight 40 to 45-minute periods per week to provide for laboratory experiences. However, they may be met by scheduling other periods of different lengths.

For the most part, school districts allocate laboratory time to high school physics and chemistry programs. It is essential to emphasize that, since earth science and biology are laboratory sciences, equal time for laboratory work should be provided in these courses as well.■

Patterns of Science Offerings

The elementary school science program (K-6), whether reading oriented or activity oriented, typically includes topics in the earth, biological and physical sciences.

Starting in Grade 7, two different patterns emerge. One, the "block" program, consists of one full year each of life science, earth science and physical science. This pattern is used in approximately 80 percent of the schools in Connecticut. The other pattern is the "spiral" or general science program. This program consists of a general science offering in Grades 7 and 8 and sometimes in Grade 9 as well.

At this level, it is recommended that all students in Grades 7, 8 and 9 be required to study science every year. If students are required to study science each year, programs must be planned that meet the needs of students of high ability, students preparing for college and students who will enter the world of work upon graduation from high school.

Two years of science are required by the state for graduation from high school. It is recommended that all students take, in addition to biology, at least one and preferably two years of physical science in the Grades 9-12 sequence.■

Electives in the Science Program

Most Grades 9-12 programs in science go beyond the basic offerings of biology, physics, chemistry and earth science. In fact, there are more than 50 other elective courses in science. A number of these are listed on page 18. Some of the more popular programs are the following (others appear in Chapter 9):

Advanced placement programs. Advanced courses go beyond the typical high school science course and usually are offered to the superior student. There are two major vehicles by which college credit may be earned within the high schools. One involves the Advance Placement (AP) programs in biology, chemistry and physics. The AP program is administered by the College Entrance Examination Board. Credit based upon successful completion of a year-end exam is accepted by most colleges in the United States.

The University of Connecticut departments of biology, chemistry and physics coordinate college-credit courses through the UConn Cooperative (Coop) Program for Superior High School Students at state high schools. Students and faculty must be accepted into the program by the respective departments. College credit awarded through the UConn Coop Program may be transferred to a number of other colleges.

College credit. High school students in Connecticut are able to earn college credit by enrolling in courses in area colleges. Several of the state's institutions of higher education allow high school students, upon the recommendation of the principal or counselor, to enroll in courses on a space-available basis for no fee or for a nominal charge. Some of the colleges charge full tuition. Colleges within a reasonable geographic area should be checked to see what arrangements can be made to accommodate interested students.

Independent study and work study. Students who are interested in obtaining college credit for work they have done in independent and/or work-study arrangements should get information about the College Level Examination Program or CLEP. This is another program which was developed by Educational Testing Services of Princeton, NJ, and is administered by institutions of higher education. Most school counselors have information about this program.

Other elective programs. Other elective programs have been built around the following:

- computer-assisted instruction;
- team teaching;
- teaching assistants (tutors with special skills or knowledge);
- use of community resources;
- contract learning or individually prescribed instruction (IPI);
- summer school enrichment;
- released-time programs;
- community or other educational programs after school or on weekends;
- work-study programs (students spend half the day or other periods of time in career-oriented placements or apprenticeships); and
- self-teaching courses, including correspondence courses which may or may not be paid for by the school.

The electives and the methods of implementation of these electives in the science curriculum are limited only by the imagination of the person(s) planning the program.■

Special Programs

A number of students who have difficulty with science concepts or with mathematical skills can benefit from instruction that will reinforce the operations or understandings underlying them.

This assistance should be directed toward the particular needs of the student as determined by the school's Planning and Placement Team (PPT). Sometimes the science instruction will be directed toward concrete operations; at other times the student will need assistance with mathematical concepts as they relate to science, or the student may have to be assigned special reading materials in order to understand the topic under study. Only when these attempts are made can it be assured that all students will be leaving their schools with the science skills and backgrounds needed to function in today's society.■

Themes In Science Programs

As the field of science continues to grow, not only is new knowledge being added at a dramatic rate, but the number of new careers in the field also is growing. By one estimate, there are over 50,000 different occupations in science and engineering. This rapid growth points out the relationships among the different disciplines in science and gives rise to what are called conceptual *schemes* – or more recently – *themes*.

Many new careers show these relationships. No longer are there just chemists, physicists and biologists. Many careers now involve occupations in fields such as biophysics, biochemistry, bioethics and environmental science. The use of themes as organizers in the science curriculum can help to show how knowledge, principles and concepts in one science subject are related to another. Some themes that have been suggested thus far are patterns, similarities and differences; and evolution, energy and the environment. It can be seen that these themes have applications in the major subject fields of chemistry, physics, earth science and biology. The themes can show the interrelatedness of these subjects as well as point the ways in which they are important in technology and even societal questions.

While a number of themes have been proposed, there is at this writing no general agreement as to what they should be. Curriculum developers should be aware of the work that is being done with themes and should make use of themes as organizers to point up the structure of their science programs.■

Special Science Offerings* In Connecticut Schools

Advanced Biology (not AP)
Advanced Chemistry
Advanced Physics
Advanced Placement Biology
Advanced Placement Chemistry
Advanced Placement Physics
Aeronautics
Allied Health
Animal Behavior
Anthropology
Astronomy
Botany
ChemCom
Chemistry for Health Science
Comparative Anatomy
Computer Science
Consumer Chemistry
Contemporary Science
Cosmology
Drug Awareness
Ecology
Electricity
Electronics
Embryology
Environmental Science
English-as-a-Second-Language Biology
Field Ecology
Genetics
Geology
Holography
Horticulture
Human Biology
Independent Study
Introduction to Physics and Chemistry
Invertebrate Zoology
Laboratory Safety
Laboratory Technology
Laser Studies
Mammalogy
Marine Science
Meteorology
Microbiology
Mineralogy
Nurse Assistant
Oceanography
Oceanography Field Work
Organic Chemistry
Ornithology
Patterns and Processes
Physical Chemistry
Physiology
Plant and Animal Care
Practical Science
Public Health
Photography
Science in the Home
Science of Cars
Science Seminar
Science Topics
Social Biology
Technology
Topics in Biology
Topics in Science
Unified Science
University of Connecticut Cooperative Program
  Chemistry
  Biology
  Physics
Vertebrate Zoology
Vocational Science

*Other than earth science, biology, chemistry and physics

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CONTENT, SKILLS AND ATTITUDES 4

> *"The principle of science, the definition, almost, is the following: The test of all truth is experiment. Experiment is the sole judge of scientific truth. But, what is the source of truth of knowledge? Where do the laws that are to be tested come from? Experiment, itself, helps to produce these laws, in the sense that it gives us hints. But also needed is imagination to create from these hints the great generalizations – to guess at the wonderful, simple, but very strange patterns beneath them all, and then to experiment to check again whether we have the right guess."*
> – Richard P. Feynman

The words of the late Dr. Richard P. Feynman, a Nobel laureate in physics, should call to the attention of any science curriculum developer the necessity for experimentation and investigation as an integral part of the program. As reinforced in this chapter, the student must be given an opportunity to participate actively in investigation and experimentation in order that he or she may derive the fullest benefits of the science program.

The educational program serves many purposes. Two of the most important are (1) to prepare individuals to become effective, contributing members of society and (2) to instill in students the skills and attitudes to allow them to realize their full potential in their professional and personal lives. As a part of the total educational offering, the science program should help all students – regardless of the occupations they choose – to better understand the natural world, to make thoughtful decisions regarding the role of science and technology, and to appreciate the promises these fields provide and the problems they generate as they contribute to shaping the world of the present and of the future.■

Connecticut's Common Core of Learning

The Connecticut State Board of Education adopted *Connecticut's Common Core of Learning* in January 1987. The philosophy underlying the development and adoption of the Common Core was that there is a "...common set of skills, knowledge and attitudes essential to the total development of all Connecticut students. These learnings have intrinsic value, independent of a student's background, for the fulfillment of future aspirations."

Connecticut' Common Core of Learning is divided into three major areas.

Attributes and Attitudes

- self-concept
- motivation and persistence
- responsibility and self-reliance
- intellectual curiosity
- interpersonal relations
- sense of community
- moral and ethical values

Skills and Competencies

- reading
- writing
- speaking, listening and viewing
- quantitative skills
- reasoning and problem solving
- learning skills

Understandings and Applications

- the arts
- careers and vocations
- cultures and languages
- history and social sciences
- literature
- mathematics
- physical development and health
- science and technology

Clearly, science and technology, as listed under Understandings and Applications, have components that fall into the categories of Attributes and Attitudes, and Skills and Competencies. Students of science must be able to read, write and communicate. They must be able to reason and solve problems as well as to demonstrate quantitative skills. And just as certainly, intellectual curiosity, motivation, persistence and self-reliance, as general elements of the Common Core, are inherent in the structure of the school science program.

More specifically, but still as overriding goals, the Common Core of Learning states that, as a result of education in Grades K-12, each student should be able to:

- understand and apply the basic principles, concepts and language of biology, chemistry, physics, earth and space science;
- understand the implications of limited natural resources, the study of ecology and the need for conservation;
- identify and design techniques for recognizing and solving problems in science, including the development of hypotheses and the design of experiments to test them – the gathering of data, presenting them in appropriate formats, and drawing inferences based upon the results;
- use observation and analysis of similarities and differences in the study of natural phenomena;
- demonstrate the ability to work with laboratory measuring, manipulating and sensing devices;
- understand the implications of existing and emerging technologies on our society and our quality of life, including personal, academic and work environments; and
- recognize the potential and the limitations of science and technology in solving societal problems.

From these goals it can be seen that the structure of the science program should contain the content and

processes of the three major areas of science study – the earth and space sciences, the life sciences and the physical sciences. In addition, the program should include an emphasis on the applications of science - the technologies. Further, the effects of scientific and technological knowledge upon society should be considered.

In its statement on the direction that science should take in the 1980s and the years ahead, the National Science Teachers Association uses the term Science-Technology-Society. Objectives for Science-Technology-Society are suggested in this chapter and should be given thoughtful consideration in the development of the science program.■

The Processes of Science

The use of science processes throughout a program in science is a must. Often the use of these processes is referred to as the *hands-on* approach to the teaching of science. However, there are more specific terms and definitions which can be used. Each of the terms has been adapted from the American Association for the Advancement of Science's program *Science: A Process Approach* (1965) and implies active student participation.

Observing. Students use their senses to learn about objects and events in their environment.

Describing. Students communicate their perceptions of what they observe.

Classifying. Students group objects according to their properties.

Comparing. Students compare and contrast the ways in which objects or events are similar or different.

Measuring. Students determine the length, area, volume, mass or other physical characteristics of an unknown quantity by comparing its value with one that is known. They also explain the causes of error and uncertainty in their measurements.

Recognizing variables. Students identify independent and dependent variables and understand the control of variables in an investigation.

Interpreting data. Students explain the pattern, trend, significance or meaning of the data derived from objects or events.

Inferring. Students develop possible explanations regarding the causes of events which may not have been observed directly.

Predicting. Students suggest the outcome of an event or process based upon their observations of the event or process.

Communicating. Students transmit information to others through the use of such devices as graphs, tables, written descriptions and oral presentations.

Formulating questions. Students originate questions based upon their experience with an event.

Experimenting. Students design and carry out procedures under controlled conditions in which variables are limited in order to obtain useful and reliable information about the interactions between objects and events.

Developing hypotheses. Students state, in testable terms, an explanation for an occurrence.■

OBJECTIVES OF THE SCIENCE PROGRAM

The objectives that follow include a number that were developed by the Connecticut Science Teachers Association (CSTA). These objectives were developed over a four-year period with the assistance of teachers throughout the state. The original set of objectives addressed the areas of content, skills and attitudes. To these areas have been added sets of objectives relating to technology and societal issues. While the objectives are presented in relatively specific terms, it should be remembered that areas of content overlap not only with other subject areas, but also with skills, attitudes, technologies and societal issues.

An overview of the major concepts appears in Tables 1-5 on pages 32-35. The specific objectives listed are arrived at gradually and may be achieved partially in earlier grades. The developmental level of the student always should be an important consideration in the presentation of these objectives and in the expectation of their mastery.

The verbs used to describe the objectives which follow – verbs such as *define, describe, explain* or *list* – may be interpreted as passive in terms of hands-on activities. Therefore, in addressing these objectives there should be an ample number of activities that are action oriented. Similarly, all experiences in science should make the fullest use of critical thinking and problem-solving approaches. Thus, there should be a generous number of investigations that involve the science processes of experimenting, measuring and observing.■

Objectives For Students Completing Grade 3

Life Science

Major Concept: Living things exhibit similarities and differences. They respire, need nourishment and water, and reproduce their own kind.

Characteristics of Life

- List similarities and differences among living things, nonliving things and things no longer living.

- Describe the variation in the appearance and habits of living things caused by seasonal changes.
- Describe changes in the appearance and habits of living things that occur during stages of their life cycle.
- List three factors that limit the number of plants and animals surviving in each generation.
- Describe several ways in which plants and animals are dependent upon each other.

Plants

- Group different seeds according to characteristics such as shape, size and color.
- List three requirements for the growth of all green plants.
- Describe the functions of roots, stems, leaves and flowers.
- Compare generations of plants and animals and list similarities and differences.
- Identify differences in various plants using leaf shape, size and texture as characteristics.
- Identify the coat, the embryo and the stored food in a seed and describe their functions.

Animals

- Classify various types of animals, e.g., birds, fish and mammals, according to their characteristics.
- Identify predators and prey and describe their relationship.
- Compare carnivores, herbivores and omnivores.
- Classify common animals as invertebrates or vertebrates.
- Construct a food chain including producers and consumers.

Humans

- Describe how food moves through the digestive system.
- Trace the movement of air in and out of the lungs and explain how this occurs.
- Describe the function of the skeleton.

Environment

- Describe how plants and animals depend upon their environments.
- Define *shelter* and describe differences in shelters.
- Define and give examples of *habitats*.

Physical Science

Major Concept: The physical world consists of matter and energy interacting.

Matter

- Identify substances that are solids, liquids and gases.
- Describe the changes in state of a solid, such as ice into water and then steam.
- Contrast physical and chemical changes.
- After testing them, group objects according to their ability to conduct thermal energy.
- Group objects according to their ability to sink or float.
- Construct an object of metal such that it will sink or float.
- Devise a test to determine the relative strength of magnets.
- Test objects for their magnetic or nonmagnetic properties and group them.

Energy

- Group materials according to their ability to conduct electricity.
- Describe some methods for conducting energy.
- Construct simple electrical circuits using batteries, wires and light bulbs.
- Describe how light energy can be obtained from heat, chemical or electrical energy.
- Demonstrate how different colors of light can be formed by a prism.
- Identify properties of sound such as pitch, volume and quality.
- Construct a device that will transmit sound.
- Construct a simple inclined plane and compare the force required to lift an object with that required to move it up the plane.
- Construct a simple balance and show how the position of the masses on either side of the fulcrum affects the balance's equilibrium.

Earth and Space Science

Major Concept: The universe is constantly changing.

- Demonstrate an awareness of the progression of and differences in the seasons.
- Locate the relative positions and motions of the sun, Earth and moon.
- Group minerals according to characteristics such as color and hardness.

- Observe weather conditions during a particular period of time.
- Describe how scientists use fossils to give us an idea of various periods in the Earth's history.
- Demonstrate an awareness of local geology and landforms.

Skill Objectives

- Measure length to the nearest scale graduation.
- Read a thermometer to the nearest graduation.
- Identity and classify objects using odor, taste, touch, sound and sight.
- Make predictions and verify accuracy, e.g., do seeds germinate better in light or in the dark?
- Weigh oneself to the nearest graduation on the scale.
- Sort and group objects according to their properties.
- Make simple quantitative estimates and verify them, e.g., estimate the number of beans in a jar and then count them.
- Make sketches from observations.
- Identify those factors which must be kept constant during an investigation.
- Develop models.

Attitudinal Objectives

- Demonstrate individual curiosity and persistence in the study of science.
- Demonstrate an understanding of the value of following the rules of safety.
- Accept, but be critical of, the evidence gathered through the methods of science.
- Be open to new information and the effect it may have on presently held beliefs.
- Develop self-confidence through the study of science by being involved in a variety of science activities.
- Demonstrate a respectful attitude toward all forms of life and the environment.

Objectives in Science, Technology and Society

- Demonstrate an awareness that advances in science and technology have allowed us to lead healthier and longer lives.
- Demonstrate an awareness that advances in science and technology have changed our ways of feeding, clothing and providing shelter.
- Demonstrate an understanding that technology, while providing us with the means for cleaner air and water, also contributes to their pollution.■

Objectives For Students Completing Grade 6

Life Science

Major Concept: All living things are made of cells and are continually interacting with their environments.

Characteristics of Living Things

- Recognize that all living things are made of cells and that the cell is their basic structural unit.
- Compare animal and plant cells. Identify their similarities and differences.
- Investigate and identify common one-celled organisms found in pond water.
- Describe the function of microorganisms in the food chain.
- Describe the hierarchy of cells, tissues, organs, systems of organs and organisms.

Plants

- Explain how plants interact with their environments.
- Describe the factors and conditions necessary for a green plant to carry out photosynthesis.
- Identify two main groups of seed plants (cone bearing and flowering) and list their characteristics.
- Describe the characteristics of nonseed plants and give examples.
- Describe the means by which flowering plants reproduce.

Animals

- Identify groups of animals without backbones (invertebrates) and list similarities and differences among them.
- List several examples of animals with backbones (vertebrates) and note their similarities and differences.
- Give examples of inherited and learned behaviors.
- List characteristics of mammals and explain why humans are classified as mammals.

- Compare characteristics of carnivores, herbivores and omnivores.
- List several behaviors necessary to the survival of some animals (e.g., camouflage, hibernation, migration, protection) and describe how these factors are important to their survival.

Humans

- Describe the effects of drugs, tobacco and alcohol upon the human body.
- Design an experiment to demonstrate the effect of exercise on heartbeat and the rate of breathing.
- Describe the major systems in the body, e.g., circulatory, digestive, respiratory.

Environment

- List environmental factors that affect the growth and development of plants and animals.
- Describe various ways in which plants and animals are interdependent with their environments.
- Construct a food chain and/or food web and describe the flow of energy in it.
- Describe the differences in climate and in geography of various biomes.
- List the characteristics of plants and animals in particular biomes, e.g., grasslands, deserts, forests, aquatic habitats.
- List several endangered species and describe why they are endangered.

Physical Science

Major Concept: The interactions of matter and energy follow patterns of nature and are reproducible.

Matter

- Compare properties of metals and nonmetals.
- Differentiate among elements, compounds and mixtures.
- Use tests such as litmus or pH paper to determine the acidity or alkalinity of water solutions.
- Describe how matter is conserved in chemical reactions.
- Construct a model of an atom showing the relative positions of the protons, neutrons and electrons.
- Describe how energy may be obtained from the fission or fusion of atoms.

Energy

- Describe what is meant by inertia.
- Describe how the change in an object's motion is affected by its mass and the force applied to it.
- Demonstrate that an action force has an equal and opposite reaction force.
- Identify gravity as the force of attraction among objects in the universe.
- Define *energy* as the ability to do work.
- Contrast kinetic and potential energy. Give examples of each.
- Construct a system in which energy is transformed from one form to another.
- Identify various forms of energy transformations (e.g., heat to light, chemical to mechanical) and give applications for each.
- Describe several means by which energy can be conserved in our environment.
- Construct an electromagnet and explain its operation.
- Demonstrate the effects of mirrors and lenses on the path of light.
- Differentiate between temperature and heat.
- Explain how conduction, convection and radiation differ in their means of heat transfer.
- Describe how temperature measurements depend upon the speed of the molecules of the substance being measured.
- Describe how various substances can be used to inhibit the flow of energy.

Earth and Space Science

Major Concept: Energy and matter in the universe are neither created nor destroyed, but can be transformed from one form to another.

Meteorology

- Identify the most common gases in the atmosphere.
- Describe the water cycle.
- Give two examples of erosion and describe them.
- Construct a simple weather instrument.
- Identify the major layers of the atmosphere.
- Collect weather data and prepare a weather forecast.

Geology

- Differentiate among igneous, metamorphic and sedimentary rocks.
- Describe the theory of plate tectonics.
- Illustrate how landforms can change as a result of volcanic action, the folding of rock layers and earthquakes.
- Identify and describe the layers of the Earth's crust.

Astronomy

- Describe how various forms of electromagnetic radiation (light, radar, lasers) are used to measure the distances to objects in space.
- Describe how a reflecting telescope works.
- Draw a diagram of constellations such as the Big and Little Dippers.
- Describe how the spectroscope is used to determine the composition of stars.
- Describe the positions of the sun, Earth and moon during the various phases of the moon.
- Diagram the orbits of the planets around the sun.

Oceanology

- Describe the factors that influence the tides of the ocean.
- Describe environments (rocky shores, sandy shores, mud flats) in the tidal zone.

Skill Objectives

- Record the results of qualitative observations.
- Design an experiment.
- Use a pan balance to mass objects to within one gram.
- Prepare a table of data.
- Mount a slide on the stage of a microscope and adjust the microscope for viewing.
- Read volumetric flasks and cylinders to the nearest graduation.
- Perform numeric calculations involving area and volume.
- Explain relationships between two variables, e.g., height and weight, drop and bounce, growth and time.

Attitudinal Objectives

- Recognize that scientific measuring devices are extensions of our senses.
- Appreciate the importance of following the rules of safety in the laboratory.
- Develop a positive approach to problem solving and the rigor of critical thought.
- Maintain an open mind in the face of information that may contradict currently held conceptions.
- Appreciate that science and technology do not provide answers to all problems in our environment.

Objectives in Science, Technology and Society

- The values of society can affect the direction of scientific research.
- Changes in science and technology affect not only the types of work we do, but the ways in which we learn.
- Advances in the technology of transportation and communication affect our relationships with people in this and other countries.■

Objectives For Students Completing Grade 8

Life Science

Major Concept 1: Living organisms carry on life functions.

- Illustrate that living organisms have life cycles, e.g., birth to death, seed to mature plant.
- Distinguish between living and nonliving things by describing life functions.
- Show that disease may be prevented by good health habits of eating, resting, exercising and hygiene.
- Describe the differences in the structure and functions of tissues and organs.
- List some of the benefits of bacterial action.
- List some of the ways that bacteria are harmful.
- Describe how to take a bacterial count.
- Describe how the body fights bacteria.
- Distinguish between viruses and bacteria.
- Describe the function of antibodies and vaccines that help to prevent and combat disease.
- Describe how health laws safeguard us against disease.
- Find patterns in data, events and life itself.
- Describe the process of photosynthesis and its dependence upon such factors as light, energy, chlorophyll, water and carbon dioxide.

- Describe basic concepts of inheritance.

Major Concept 2: Living organisms and their environments are interdependent and are constantly interacting.

- Illustrate and describe the water cycle.
- Describe the predator-prey relationship.
- Give reasons for the need to conserve soil.
- Compare, contrast and discuss food chains and food webs.
- Define symbiosis and give examples of this relationship.
- Describe the carbon-hydrogen-oxygen cycle.
- Describe the nitrogen cycle.
- Describe what soils are and how they are formed.

Major Concept 3: Living things evolve.

- Describe ways in which the environment is always changing and how organisms must be able to adjust to these changes in order to survive.
- Describe how each plant and animal goes through a series of changes as part of its individual life cycle.
- Describe how living things have changed over the long period of the Earth's history.
- Discuss the fact that many plants and animals have been unable to adapt to changing environments and have become extinct.
- Describe evidence provided by fossils that indicates many forms of life (e.g., trilobites, dinosaurs, and sabertooth tigers) have become extinct and relate this to environmental changes.
- Describe how organisms and their environments constantly are interacting and are interdependent. (The activities of plants and animals can change the environment and changes in the environment can affect plants and animals.)
- Describe how changes in structure and behavior from one generation to the next are usually the result of genetic changes.

Physical Science

Major Concept: There are patterns of similarities and differences in the interactions of matter and energy.

- Give examples of different forms of energy. Discuss similarities and differences.
- Identify three basic parts of an atom (electron, proton and neutron), their charges and relative locations.
- Differentiate among solids, liquids and gases, and describe their properties by using the kinetic molecular theory.
- Relate how an energy change is involved whenever there is a change in state (phase) of matter, e.g., water to steam, etc.
- Describe how forms of energy may be changed into other forms of energy.
- Define a *calorie* and differentiate between the *calorie* and the *Calorie* (kilocalorie).
- Identify sources of nuclear energy.
- Compare *fission* and *fusion*.
- Demonstrate an awareness that atomic energy results from the conversion of nuclear mass into energy.
- Differentiate among and give examples of the following forces: adhesion, cohesion, capillarity, surface tension, gravity and friction.
- Describe some of the factors which affect the flow of electrons through substances.
- Describe the relationship of temperature to the kinetic molecular theory.
- Define and illustrate the differences between kinetic and potential energy.
- Describe patterns in the Periodic Chart of the Elements.
- Identify density as a relationship between mass and volume.
- Define and distinguish between *mass* and *weight*, and between *mass* and *volume*.
- Describe how electrical energy can be used to operate devices such as the radio, telephone, computer, etc.
- Demonstrate how sound is generated, transmitted and received.
- Design a simple experiment demonstrating reflection and refraction.
- Describe how white light is composed of and may be divided into many colors.
- Classify from a group of objects those which are good or poor conductors of electricity.
- Conduct an experiment which shows changes that take place as the result of a common chemical reaction, e.g., vinegar and baking soda, lime water and carbon dioxide, the rusting of iron.

Earth Science

Major Concept: The universe is constantly changing.

- Describe the life and death of a star.
- Distinguish between a solar and a lunar eclipse.
- Describe how the moon influences the tides.
- Explain how the sun affects the Earth's climate and weather.
- Describe the methods by which sedimentary, igneous and metamorphic rock are formed.
- Contrast various kinds of weathering.

Skill objectives

- Use measuring devices and record data properly.
- Collect data and use them to make graphs and charts.
- Interpret data, charts and graphs, and make generalizations.
- Follow directions, conduct simple tests and interpret results.
- Employ the mathematics necessary to convert units within the metric system.
- Develop a hypothesis from basic data and devise a method to test it.
- Use, maintain and care for laboratory equipment.
- Distinguish between qualitative and quantitative observations.
- Follow laboratory safety rules at all times.
- Use scientific methods for setting up experiments which have independent and dependent variables.
- Communicate information organized in logical sequences verbally and graphically using related vocabularies.
- Recognize that certain teaching devices, such as a "model," are only aids and are not reality.
- Apply scientific theories and laws to a given situation.

Attitudinal Objectives

- Demonstrate the value of following the rules of safety.
- Exhibit self-confidence through the study of science by being involved in a variety of scientific activities.
- Evaluate evidence gathered through scientific methods.
- Demonstrate individual curiosity and persistence in the study of science.
- Develop a longing to know and understand, a questioning attitude, the desire to search for data, the desire to demand verification, a respect for logic, and a consideration of premises and consequences.

Objectives in Science – Technology – Society

- Describe how pollutants affect our environment. List steps that may be taken to control them and protect our surroundings.
- Trace the growth of human population and describe possible futures for such growth.
- List several hazardous substances. Describe their origins, use and effects on the community. Propose means for disposing of them.
- Describe causes for an energy shortage and suggest ways in which these shortages can be resolved.■

Objectives For Students Completing Grade 12

Life Science

Major Concept 1: All living things have basic needs.

- Discuss the fact that living things must have water and nourishment in order to respire and reproduce to continue the species.
- Discuss the proper care of laboratory animals and treatment of domestic animals and wildlife.
- Discuss the proper care of plants in the laboratory, greenhouse, at home and out-of-doors, and the importance of preserving wildflowers, plants, bushes and trees.

Major Concept 2: Knowledge of the dynamics of ecology is essential for intelligent planning and decision making.

- Define an ecosystem and compare biotic and abiotic factors.
- Describe adaptations of organisms for survival in a particular ecosystem.
- Identify and describe a predator-prey relationship.

Major Concept 3: Living things require energy and there must be an interchange of energy in a balanced environment if living things are to survive.

- Explain the relationship among producers, consumers and decomposers.
- Compare and contrast photosynthesis and cell respiration.
- Explain the relationship between a food chain and a food web.

Major Concept 4: The cell is the basic structural and functional unit of most living things.

- Explain the relationship among cells, tissues, organs and systems.
- Identify the organelles of the cell and explain their functions.
- Compare and contrast mitosis and meiosis and explain the purpose of these processes.

Major Concept 5: A pattern of inheritance can be observed over a long period of time.

- Explain the difference between asexual and sexual reproduction.
- Illustrate Mendel's laws of inheritance.
- Describe the chemical nature of genes and chromosomes and their roles in maintaining genetic continuity.
- Discuss benefits and concerns of genetic engineering.

Major Concept 6: Correct information about the human body will aid the individual in daily life and make one a more efficient and responsible human.

- Illustrate the structure and function of human body systems.
- Discuss the following as they relate to health: human growth, development and disease; hygiene; drugs, alcohol and nicotine; nutrition; food additives and imitation foods; and environmental concerns.

Major Concept 7: Some microorganisms cause disease and others are beneficial.

- Discuss the role of bacteria in health and disease.
- Illustrate the methods by which pathogenic organisms can be transmitted.
- Explain active immunity and how it is acquired.
- Compare and contrast bacteria, viruses and fungi.

Major Concept 8: There is an increasing order of complexity in living organisms.

- Select two animals from different phyla; compare their structures and how the animals carry on life functions.
- Select two plants ranging from mosses to angiosperms and gymnosperms and compare structure and how the plants carry on life functions.

Physical Science

Major Concept 1: Matter is composed of molecules, atoms or ions whose interactions, when observed and measured, are found to follow natural laws.

- Distinguish between atoms and molecules.
- Distinguish between elements, compounds and mixtures.
- Identify the physical state (phase) of a substance.
- Locate protons, neutrons and electrons in the present model of the atom and state the charge on each.
- Describe how molecules are composed of atoms bonded together.
- Substantiate that chemical reactions result in new substances with new properties.
- Discuss why and how in ordinary chemical reactions, the total mass of reactants must equal the total mass of products.
- Describe general properties of acids, bases (alkalis) and salts and describe the neutralization process.
- Compare and contrast a physical and a chemical change.
- Describe how an ion is a charged particle and an atom is a neutral particle.
- Identify the solute and solvent in a solution.
- Describe the relationship between atomic structure and the properties of the elements.
- Identify the symbols of common elements.
- Distinguish between simple organic and inorganic compounds.

Major Concept 2: Energy exists in many forms which are interconvertible through reactions with matter.

- Differentiate between situations illustrating kinetic energy and potential energy.
- Describe the effect of temperature on the physical state (phase) of a substance.
- Substantiate that chemical reactions are accompanied by energy changes.
- Describe the difference between temperature and heat.
- Predict the effect of temperature change and of pressure change on the volume of a gas.
- Discuss the relationship between molecular motion and temperature.
- Describe the relationship between molecular motion and pressure.
- Define what is meant by a *gas*, *liquid* and *solid* in terms of size and shape.

- Define *work* and do simple problems involving *work*.
- Compare velocity and speed.
- Define and give examples of *forces*.
- Describe the factors that influence the rate of a chemical reaction.
- Discuss the phase changes associated with the melting point and with the boiling point of a substance.
- Define *electricity*.
- Explain the ways in which static electricity, alternating current (AC) and direct current (DC) differ.
- Cite evidence that, under ordinary circumstances, matter and energy can be converted from one form to another with no loss or gain.
- Explain how different classes of simple machines operate.
- Define *acceleration*.
- Describe the relationship between the quantity of material and the heat content of a substance.
- Define *friction* and give examples of its advantages and disadvantages.
- Cite evidence that matter and energy are interconvertible but the sum total of these remains constant.
- Discuss electromagnetic radiation as a form of energy.
- Describe the reflection and refraction of light.
- Describe sound and explain it as a form of energy.

Earth Science

Major Concept: Geological, meteorological, oceanological and astronomical processes follow physical laws.

- Define the study of *astronomy* as relating to galaxies, star systems and space.
- Illustrate that geology concerns itself with historical geology, the story in the rocks, earth chemistry and the restless earth.
- Discuss the limits of the Earth's energy resources.
- Recognize the dynamic nature of the Earth.
- Discuss oceanography as concerned with the chemistry of oceans, marine biology, marine topography, and motions of tides, waves, currents and shorelines.
- Discuss how meteorology is concerned with weather, air and its movements; chemical and physical properties of gases; air masses; motion caused by the sun's energy; weather maps and forecasting.
- Discuss the energy source for earthquakes, thunderstorms, ocean currents and starlight.
- Illustrate the rock cycle.

Skill Objectives

- Interpret results.
- Set up controls or standards.
- Communicate acquired knowledge graphically, quantitatively and verbally.
- Use the specific vocabulary related to each topic under study.
- Demonstrate skill in the use of appropriate techniques, instruments, equipment and test kits within each discipline, as required.
- Select and assemble appropriate equipment and conduct experiments.
- Make necessary observations and report the data in an appropriate and logical format.
- Consider alternative solutions.
- Identify a problem and state it clearly.
- Examine the literature for ideas related to problems under consideration.
- Design, conduct, evaluate and communicate the results of experiments with multiple variables.

Attitudinal Objectives

- Be aware of the importance of biology as a study of living things in relationship to oneself.
- Develop appreciation for critical thinking as used in the practice of science.
- Demonstrate a willingness to cooperate in class and laboratory.
- Appreciate that one's genetic characteristics and environmental factors work together to comprise the individual's total being.
- Develop attitudes that are built upon fact and logic.
- Demonstrate a better understanding of the advantages and problems in the everyday world brought about by society's use and misuse of scientific knowledge.
- Appreciate the potential for careers in the sciences and science-related fields.
- Observe rules of safety in the laboratory and field.
- Recognize that the physical universe obeys specific laws.
- Appreciate that different points of view develop when citizens must make decisions on problems involving science.
- Demonstrate the development of a personal

value system regarding the environment by willingness to adjust one's lifestyle to be in harmony with ecological laws.

Objectives in Science – Technology – Society

- Describe several problems involving the management of nuclear waste.
- Analyze the distribution of food resources and suggest ways in which the food requirements of a growing world population can be met.
- Describe the growth and extinction of various species of animals and plants. Analyze the results of endangered species laws.
- List several concerns regarding our water resources, e.g., contamination by disposal, leaching and runoff of chemicals. Suggest the means for addressing these concerns.
- List several concerns about recombinant DNA research. Describe how these concerns are being addressed.
- Outline the effects of high technology in this country on employment, the competitiveness of our economy and upon our system of education.

Basic Science Concepts, Skills and Attitudes For Students Completing Grades 3, 6, 8 and 12 In Connecticut Schools

LIFE SCIENCE	
GRADE 3	• Living things exhibit similarities and differences. They respire, need nourishment and water, and reproduce their own kind.
GRADE 6	• All living things are made of cells and continually are interacting with their environments.
GRADE 8	• Living organisms carry on life functions. • Living organisms and their environments are interdependent and constantly are interacting. • Living things evolve.
GRADE 12	• All living things have basic needs. • Knowledge of the dynamics of ecology is essential for intelligent planning and decision making. • Living things require energy and there must be an interchange of energy in a balanced environment if living things are to survive. • The cell is the basic structural and functional unit of most living things. • A pattern of inheritance can be observed over a long period of time. • Correct information about the human body will aid the individual in daily life and make one a more efficient and responsible human. • Some microorganisms cause disease and others are beneficial. • There is an increasing order of complexity in living organisms.

Table 1

PHYSICAL SCIENCES	
GRADE 3	• The physical world consists of matter and energy interacting.
GRADE 6	• The interactions of matter and energy follow patterns of nature and are reproducible.
GRADE 8	• The physical world consists of interactions of matter and energy.
GRADE 12	• Matter is composed of molecules, atoms or ions whose interactions, when observed and measured, are found to follow natural laws. • Energy exists in many forms which are interconvertible through reactions with matter.

Table 2

EARTH AND SPACE SCIENCE	
GRADE 3	• The universe is constantly changing.
GRADE 6	• Energy and matter in the universe are neither created nor destroyed, but can be transformed from one form to another.
GRADE 8	• The Earth and solar system undergo changes involving different cycles.
GRADE 12	• Geological, meteorological, oceanological and astronomical processes follow physical laws.

Table 3

SKILLS	
GRADE 3	• Measure • Classify • Observe • Identify • Sort, Group • Estimate • Draw conclusions
GRADE 6	Grade 3 skills plus: • Record the results of qualitative observations. • Design an experiment. • Mass objects within one gram on a pan balance. • Perform numeric calculations involving area and volume. • Explain relationships between two variables, e.g., height and weight, drop and bounce, growth and time.
GRADE 8	Grade 6 skills plus: • Prepare and interpret graphs and charts. • Develop a hypothesis and devise a method to test it. • Employ necessary math to convert units within the metric system. • Use, maintain and care for laboratory equipment. • Communicate • Use "scientific methods" for setting up experiments.
GRADE 12	Grade 8 skills plus: • Set up controls or standards. • Consider alternative solutions. • Select and assemble appropriate equipment for experiments. • Design, conduct, evaluate and communicate the results of experiments with multiple variables.

Table 4

ATTITUDES	
GRADE 3	• Curiosity • Value of the rules of safety • Critical thought • Open-mindedness • Self-confidence
GRADE 6	Grade 3 attitudes plus: • Understand that science and technology do not provide answers to all environmental problems. • Realize the importance of measuring devices as extensions of our senses.
GRADE 8	Grade 6 attitudes plus: • Questioning attitude • Evaluate evidence • Demand verification • Consider the consequences of action • Respect for logic
GRADE 12	Grade 8 attitudes plus: • Appreciate different points of view on problems involving science and technology. • Develop personal values regarding harmony with environment. • Understand advantages and problems brought about by use and misuse of scientific knowledge.

Table 5

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Science For Students With Special Needs 5

> *"Every man who rises above the common level has received two educations; the first from his teachers; the second, more personal and important, from himself."*
> – Edward Gibbon

Connecticut Requirements
The Physically Disabled Child
The Learning-Disabled Child
The Mentally Disabled Child
The Deaf or Hearing-Impaired Child
The Blind or Visually Impaired Child
Science for the Gifted

No child is born mildly retarded or learning disabled in the same way that a child is born male or female or with blood type O negative. The decision that an individual is retarded is a judgment based on the way he or she performs certain tasks. As Jane Mercer (1973) has stated, "Persons have no names and belong to no class until we put them in one. Whom we call mentally retarded, and where we draw the line between the mentally retarded and the normal, depend on our interest and the purpose of our classification."

In the past, labels were used to place students in groups to determine if these students were eligible for special services in the school or community. The focus of special education was diagnosis and classification. Once the student was classified, he or she started to receive appropriate "treatment" in a special setting, usually a room away from the rest of the students in the school. This procedure was based upon models in medicine, where the illness is diagnosed and treatment is prescribed.

Unfortunately, few specific "treatments" automatically follow from the diagnosis of children with special needs such as behavior disorders, emotional disturbances, mental retardation and other physical or emotional disabilities. There are many different teaching strategies and materials which can be used with students who are labeled retarded. A student who has been classified as visually impaired may benefit from the same techniques used to teach students who can see, but who have trouble remembering what they see. One might argue that labeling students has no educational relevance, since the label does not tell the teacher(s) which methods or materials should be used with individual students.

To help students with special needs, teachers need to know which instructional strategies to use with the individual student. Most science teachers are unaccustomed to working with special students and are somewhat apprehensive about having a disabled student in their classrooms. Once reasonable modifications to the course have been made, the programs usually are successful and the integration of the disabled student provides a rewarding experience for both teachers and students.■

Connecticut Requirements

How are the modifications to the science course of study arrived at? First, every Connecticut school district must offer a free, appropriate public education for students between the ages of 3 and 21 who have been identified as disabled. A major feature of this state requirement is the emphasis on the regular classroom as the preferred instructional base, whenever appropriate. This philosophy or approach to educational programming for disabled children is termed the principle of the least restrictive environment. Placement in the least restrictive environment ensures that disabled students are educated with nondisabled students, i.e., mainstreamed to the maximum extent appropriate.

The least restrictive environment provision also ensures that the placement of a disabled child outside the regular classroom occurs only when the nature or severity of the disability is such that education in regular classes with the use of supplementary aids and services cannot be achieved satisfactorily. A school identifies the least restrictive environment for a particular student by holding a meeting of the Planning and Placement Team (PPT), in which an Individual Education Program (IEP) for the student is planned. The IEP is developed by the student's teacher or teachers, one or both parents, a qualified school official and the student (whenever possible). Other specialists may be involved if the parent(s) or the public agency (school) so desire.

Each IEP must include the following:

- the child's present level of educational performance;
- annual goals, including short-term instructional objectives;
- specific special education and related services to be provided to the child, and the extent to which the child will be able to participate in regular educational programs;
- projected dates for initiation and anticipated duration of special services; and
- objective criteria, evaluation procedures and schedules for determining on at least an annual basis whether or not the short-term instructional objectives are being met.

Every school district has a standard set of forms for developing the IEP. Many school systems use word processing and/or database management programs to assist the PPT in developing the IEP.

Special education staff members and classroom teachers should consult regularly to plan activities, demonstrate special materials or suggest specific approaches to be used when working with children who have special educational needs. References to publications and organizations dealing with disabled youngsters appear at the end of this chapter.

Special needs children include those with:

- mental disabilities;
- physical and health disabilities (epilepsy, cerebral palsy);
- impaired vision or hearing;
- communication disorders (speech impairment, articulation disorders – voicing problems);

- behavior disorders, whether emotional disturbance or social maladjustment;
- learning disabilities;
- multiple and severe handicaps; and
- special abilities – the gifted and talented.

The school district's planning and placement teams may decide to educate certain more severely disabled students in special classes or separate programs. This recommendation would be made when the team feels that the student would be unable to participate in the regular program even with possible modifications.

One of the key ingredients in a successful mainstreaming experience is the teacher's attitude toward both the individual child and the concept of mainstreaming. The relationship among the disabled child, the teacher and the class must be positive for mainstreaming to be successful. Teachers who have successful experiences with mainstreaming are those who see all children as individuals, get to know their strengths and weaknesses and attempt to meet their individual needs.

Some basic, general principles that teachers should follow when working with disabled children are the following:

- The individual pupil-teacher relationship is of paramount importance. The relationship should be based on the nature of the disability, mutual trust, praise for positive action and a great deal of patience.
- Learning should proceed slowly and gradually, yet deliberately. Concepts may have to be developed over long periods of time.
- Science learning should begin with objects, events and words that are most familiar to the child.
- In most disabling conditions, language growth will be needed, since the child has suffered from limited exposure.
- Time should be allocated to get to know how the individual child learns best – the child's learning style, rate of learning and interest (Jacobson and Bergman, 1987).■

The Physically Disabled Child

Science instruction should be an integral part of the education of disabled students from kindergarten through high school. Disabled children possess the same need, curiosity and enthusiasm to explore and investigate their environments as do all children. These students should receive the same comprehensive exposure to the fields of science as do nondisabled students. The curriculum for disabled students should include content, process and career education. Instructional strategies, techniques and procedures found to be effective with nondisabled students are those also found to be effective with physically disabled students.

Listed below are some recommendations to take into account when a school system is preparing a curriculum for physically disabled students. The following were developed during a National Science Teachers Association conference, during which science for the physically disabled student was explored.

Career Concerns. Disabled students should have equal opportunities to pursue science-related careers.

Teacher Education. Preservice education programs should prepare prospective classroom personnel to teach science to disabled students. In-service programs should provide school personnel with access to current information on teaching science to disabled students.

Methods. Methods used in teaching science to physically disabled students should provide opportunities for them to learn how to be independent learners and how to interact with nondisabled persons.

Materials/Programs. Special consideration should be given to the identification and development of instructional materials and programs that will help eliminate the barriers to the study of science for physically disabled students.

Dissemination. In order for classroom teachers and counselors to plan and implement desirable science programs for physically disabled students, it is essential that they have ongoing access to current and relevant information about science programs and instructional approaches for them.

Evaluation/Assessment. In the absence of a body of empirical knowledge on teaching science to disabled students, systematic efforts to gather, organize, synthesize and disseminate this knowledge should be conducted. Modifications in the evaluation program may have to be made for the disabled student.

Education Organizations and Agencies. Each professional education organization and agency should be actively concerned with the rights and needs of physically disabled students to be taught science in an appropriate classroom setting. Most current science programs can be used by the physically disabled student. However, there is one project – Science Enrichment for Learners with Physical Handicaps (SELPH) – which is an adaptation of the Science Activities for Visually Impaired (SAVI) project and which produces units of study and equipment for the orthopedically disabled child (see Resources at end of chapter).■

The Learning-Disabled Child

There are a number of diagnostic terms which fall under the heading of learning disability. Elaboration upon these numerous diagnostic terms is beyond the scope of this guide.

A learning disability may be described as a condition or set of conditions that severely interferes with an individual's ability to benefit from educational experiences. Learning-disabled students do not appear to learn in the ways that most other students do. These students usually are identified when a wide discrepancy occurs between a child's school achievement and his or her intellectual potential. Emotional, physical, neuropsychological or sensory-perceptual factors may be the cause of the learning disability. Included among the more common indicators are the following (Jacobson and Bergman, 1987):

- a high degree of distractibility;
- a low tolerance for frustration;
- difficulty in working in a large-group setting;
- an inflexibility of thought generally associated with a younger child;
- an awkward gait;
- a poor self-image;
- coordination problems in copying or tracing or hitting a ball;
- poor auditory or visual memory;
- a tendency to become easily confused or muddled;
- an inability to follow directions containing more than two specific commands;
- a marked dependency upon adults; and
- spontaneous expression of feeling.

As one reviews these traits, it becomes clear why many of these children are never identified and referred for special services. Some broad guidelines for working with these children can be given. For example, when working with a learning-disabled student the teacher must know the child well, know his or her strengths, personality and learning styles. Parents, doctors, special educators and administrators can assist in identifying the problem areas with which the child needs help. Once these are identified, special materials or approaches may be developed.

At the present time, there are no published special science programs for the learning-disabled child. As a general practice, learning disabled students receive their science instruction in mainstream classes. This is why it is important that the teacher know the child's learning needs as identified by the PPT. With this kind of information, the teacher can design alternate learning exercises.■

The Mentally Disabled Child

Children who are classified as being mentally disabled exhibit development lags in general maturation, cognitive ability and social adjustment. The vast majority of children with mental retardation are mildly disabled and can benefit from much of the regular science program. Usually it takes these students more time to learn some fact or concept, and they may be unable to retain as much information as other children. These students often have difficulty recalling, transferring, conceptualizing and generalizing. These handicaps have important implications for teachers who are planning science programs.

When modified programs are created for these students, the teacher should make certain that concrete and firsthand experiences abound. The program should be flexible enough to follow the child's curiosity whenever possible and appropriate. Activities planned should be such that they usually allow the student to complete the activity and be successful.

The Biological Science Curriculum Study (BSCS) Group has developed two science programs for mentally disabled students: "Me Now" for students in the intermediate grades and "Me and My Environment" for children in the middle school/junior high grades (see Hubbard listing in Resources).

Several projects funded by the National Science Foundation, "Science – A Process Approach" (SAPA), "Science Curriculum Improvement Study" (SCIS), "Elementary Science Program" and the "Elementary Science Study," have been adapted for use with these students (see Delta listing in Resources).■

The Deaf or Hearing-Impaired Child

Most science programs in the marketplace can be used with deaf children, although some adaptations may have to be made in some of the activities. This would be especially true in certain units dealing with sound. The teacher may have to do more writing on the chalkboard. Instructions for certain activities may have to be acted out or illustrated by models, pictorial representation, printed words or in rebus form. Task cards may be used for the children who can read.

The "Science Curriculum Improvement Study" (SCIS) program has materials that have been adapted for deaf children. Additional information on this topic is found in *Science for Deaf Children* (Leitmen, 1968).■

The Blind or Visually Impaired Child

When working with blind or visually impaired children, many procedures should be tried. Some of these procedures include the following:

- Stress tactile and auditory conversations in science work.
- Children also can uncover information about objects through smell or taste.
- Whenever possible, blind or visually impaired children should participate in science work along with sighted peers. Pairing children often is a successful strategy.
- Sufficient opportunities for free and individual investigations should be provided. Blind children often need a greater amount of time to explore objects than their sighted peers. As children get to know a variety of objects well, their confidence and independence will grow.
- Adapt exercises or activities so that blind children can participate in them, e.g., instead of sorting objects from a kit according to purely visual characteristics, the blind child can accomplish the goal of sorting by grouping the objects by shape, sound, texture, odor, etc.
- Instructions for activities can be provided using tape recorders, Braille labels (if available), or directions read to blind students by the teacher or another student. When providing instructions either orally or on tape, it is best to use terms that already are familiar to the child.
- Language development can be encouraged while the child is manipulating an object or performing an operation, e.g., as a child feels a block, he or she should be asked to describe it fully.
- If a new term is to be provided, it should be done clearly and while the child is experiencing the meaning, sensation or characteristic associated with the word.
- Successful experiences should be planned in order to build independence. While praise should not be given indiscriminately, it should be provided often nough to sustain and build growing confidence.
- Materials to be used with blind children should be selected with great care so as to provide maximum sensation while taking precautions not to introduce dangerous (e.g., sharp or pointed) objects.

The staff at the Lawrence Hall of Science, University of California at Berkeley, has developed a science program called "Science Activities for the Visually Impaired" (SAVI). The materials designed for this program are intended to be used with students in Grades 4 through 7. When field tested, these materials were found to be effective with children who had other disabilities. This discovery led to the "Science Enrichment for Learners with Physical Handicaps" (SELPH) Project.

In the 1970s, the University of California at Berkeley instituted a program entitled "Adapting Science Materials for the Blind" (ASMB). This project team has adapted commercial science programs for use with blind children. ASMB has produced a version of SCIS that is fully adapted for the blind (see Resources at end of chapter).■

Science for The Gifted

One of the major problems facing teachers today is how to provide for the gifted child within the basic science curriculum. Most programs for the gifted tend to focus on language arts activities, reading and art experiences. The special needs of these students in the curricular areas of science and mathematics frequently are neglected. It has been recommended that since the multitalent approach to identification of the gifted (above average ability, task commitment, creativity) now is widely advocated, it makes some sense to provide special learning experiences for the gifted in relation to their areas of high potential. This means that the student with science ability should be steered toward a special science program and the gifted art student to that area and so on. The danger of this approach is the possibility of focusing instruction only on a gifted student's high ability area. This may prove to be counterproductive to the individual's general intellectual development. Many gifted children have special abilities in a variety of areas and a program designed too rigidly may limit the number of opportunities that could be made available.

A well-designed gifted program should provide opportunities for both broad general development of the individual and for areas of specialization, such as science. Thus, there is a need for program growth in two dimensions: breadth and depth. A well-trained resource teacher can fill the need for providing a creative enrichment program involving thinking skills, aesthetics, problem-solving and project activities. Meanwhile, the focus on depth may come from programs which allow the opportunities for specialized study in a curriculum area (see Resources at end of chapter).

Specialized programs for the gifted may mean three different things: acceleration, enrichment or a method of grouping.

Acceleration. Acceleration or advancement refers to the idea of leap-frogging ahead or skipping grades. This also can mean early admission to kindergarten or first grade, or perhaps a compressed high school curriculum that permits students to graduate a semester or full year ahead of schedule. It also may mean an in-depth study of more challenging topics, more thorough learning of regular topics, or extension of the subject matter or correlated areas.

There are other methods of acceleration that may reduce the social and emotional problems that can occur when a child is moved into classes with older children. A third grader who is a whiz in arithmetic might go to the sixth grade classroom for mathematics but spend the rest of the day with his or her third grade peers. (This semi-separation approach is practiced by many schools in Connecticut.) Or a high school student may be released from school part time to attend courses at a local college.

Enrichment. Instead of using the existing school structure to provide challenges for the gifted, enrichment offers different types of learning opportunities. The learning process can be enriched by different curriculum materials, individual instruction, emphasis on the higher mental processes of divergent thinking and creativity, independent study, problem-solving projects, and any number of techniques that give gifted youngsters a welcome change from the routine of the regular classroom. But a difference in curriculum is not sufficient for the gifted science student; rather, a challenging difference is what is required.

Individual instruction may come from the regular teacher in the classroom or be provided by specially trained teachers in resource rooms where the gifted and talented in a school (or a city) spend time with their particular interests. In some school districts resource rooms may be staffed by a teacher who travels from school to school.

Another form of enrichment is a mentorship program through which local citizens, such as scientists, artists or business people, work closely with gifted children, sharing expertise with them and fostering the students' talents.

Grouping. This is considered by some to be a controversial approach to meeting the needs of the gifted. Some critics feel that separating bright children from the others fosters a sense of elitism and prevents the "average" students from learning from their more-talented classmates. Advocates say the gifted may learn more if they are grouped with their intellectual peers and receive the essential challenge provided by other bright students.

As with acceleration, grouping can be accomplished in a variety of modes. Some school districts provide complete separation, with special schools or special classes within a school that the gifted and talented attend full time, e.g., the Bronx High School of Science and the North Carolina School of Science and Mathematics. More commonly, arrangements are made to allow all gifted students in a particular grade to be placed in the same class but not with the entire class population. This method is the one most frequently used in Connecticut schools. Students spend part of the day with their classmates but the rest of the day with other gifted students who may be younger or older.

Grouping may be considered another form of enrichment. It can involve such things as special Saturday classes, summer programs at universities, and field trips or other special projects outside regular school hours.

Whatever the approach or combination of approaches, a good-quality gifted program should offer both creative enrichment and a specialization of study. Both are essential for a full and maximum development of the gifted child. Creative enrichment cuts across all areas of special talent, while specialized study provides a focus for a student's special abilities. A vital criterion for any special program is that it truly gives the student a significant challenge and is not simply busywork. The work should not only be more advanced, exciting and permit delving into subjects in depth, but it also should encourage independent learning.■

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Resources

Books and Journals

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Exceptional Children. Council for Exception Children, 1920 Association Drive, Reston, VA 22091.

Exceptional Children in the Regular Classroom. Council for Exceptional Children, 1920 Association Drive, Reston, VA 22091.

Education of the Visually Handicapped. Association for the Education of the Visually Handicapped, 919 Walnut Street, 4th Floor, Philadelphia, PA 19107.

Hoffman, H., and Ricker, K. *Science Education and the Physically Handicapped*. Washington, DC: National Science Teachers Association, 1979.

Journal of Learning Disabilities. Professional Press Inc., 101 E. Ontario Street, Chicago, IL 60611.

Journal of Special Education. Grune and Stratlon, Inc., 111 Fifth Avenue, New York, NY 10003.

Journal of Visual Impairment and Blindness. American Foundation for the Blind, 15 West 16th Street, New York, NY 10011.

Linn, M.C., and Peterson, R.W. "The Effect of Direct Experience with Objects on Middle Class, Culturally Diverse and Visually Impaired Young Children." *Journal of Research in Science Teaching* 20: 183-190. 1973.

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Teaching Exceptional Children. Council for Exceptional Children, 1920 Association Drive, Reston, VA 22091.

The Volta Review. Alexander Graham Bell Association for the Deaf, 3417 Volta Place, NW, Washington, DC 20007.

Publications Dealing With the Gifted Child

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Connecticut State Department of Education. *CONN-CEPT II – Connecticut's Programming for the Gifted and Talented: Differentiated Curriculum for the Gifted and Talented in Science and Mathematics*. Edited by D. LaSalle, et al. Hartford, CT: Connecticut State Department of Education, 1978.

Connecticut State Department of Education. *CONN-CEPT III – Connecticut's Programming for the Gifted and Talented: Once Upon A Building*. Edited by P. Cobb, S. Cobb and C.M.E. Dow. Hartford, CT: Connecticut State Department of Education, 1978.

Connecticut State Department of Education. *CONN-CEPT V – Connecticut's Programming for the Gifted and Talented: Task Force Report on Identification*. Revised Edition. Edited by A. White. Hartford, CT: Connecticut State Department of Education, 1978.

Connecticut State Department of Education. *CONN-CEPT VII – Connecticut's Programming for the Gifted and Talented: Task Force Report on Curriculum*. Revised Edition. Edited by A. White. Hartford, CT: Connecticut State Department of Education, 1978.

Connecticut State Department of Education. *CONN-CEPT IX – Identifying and Programming for Hispanic Gifted and Talented Students*. Edited by Miranda et al. Hartford, CT: Connecticut State Department of Education, 1980.

Connecticut State Department of Education. *CONN-CEPT X – Differentiated Curriculum in Marine Studies/Computer Science for the Gifted and Talented*. Edited by Haakonsen and Danielson. Hartford, CT: Connecticut State Department of Education, 1980.

(continued)

Organizations Which Help Disabled Learners and Their Teachers

Adapting Science Materials for the Blind (ASMB) and Science Activities for the Visually Impaired (SAVI). Lawrence Hall of Science. University of California at Berkeley, Berkeley, CA 94720.

American Printing House for the Blind, P.O. Box 6085, Louisville, KY 40206.

Alexander Graham Bell Association for the Deaf, 3417 Volta Place, NW, Washington, DC 20007.

Biological Sciences Curriculum Study, P.O. Box 930, Boulder, CO 80302.

Chemistry Department, American University, Washington, DC 20009.

Council for Exceptional Children, 1920 Association Drive, Reston, VA 22091.

Delta Education Inc. (SCIS and ESS materials), P.O. Box M, Nashua, NH 03060.

Hubbard Scientific Company (biology materials for the mentally disabled), P.O. Box 104, 1946 Raymond Drive, North Brook, IL 60062.

Institute for Research on Exceptional Children, University of Illinois, Urbana, IL 61801.

National Center on Education Media and Materials for the Handicapped, Ohio State University, Columbia, OH 43210.

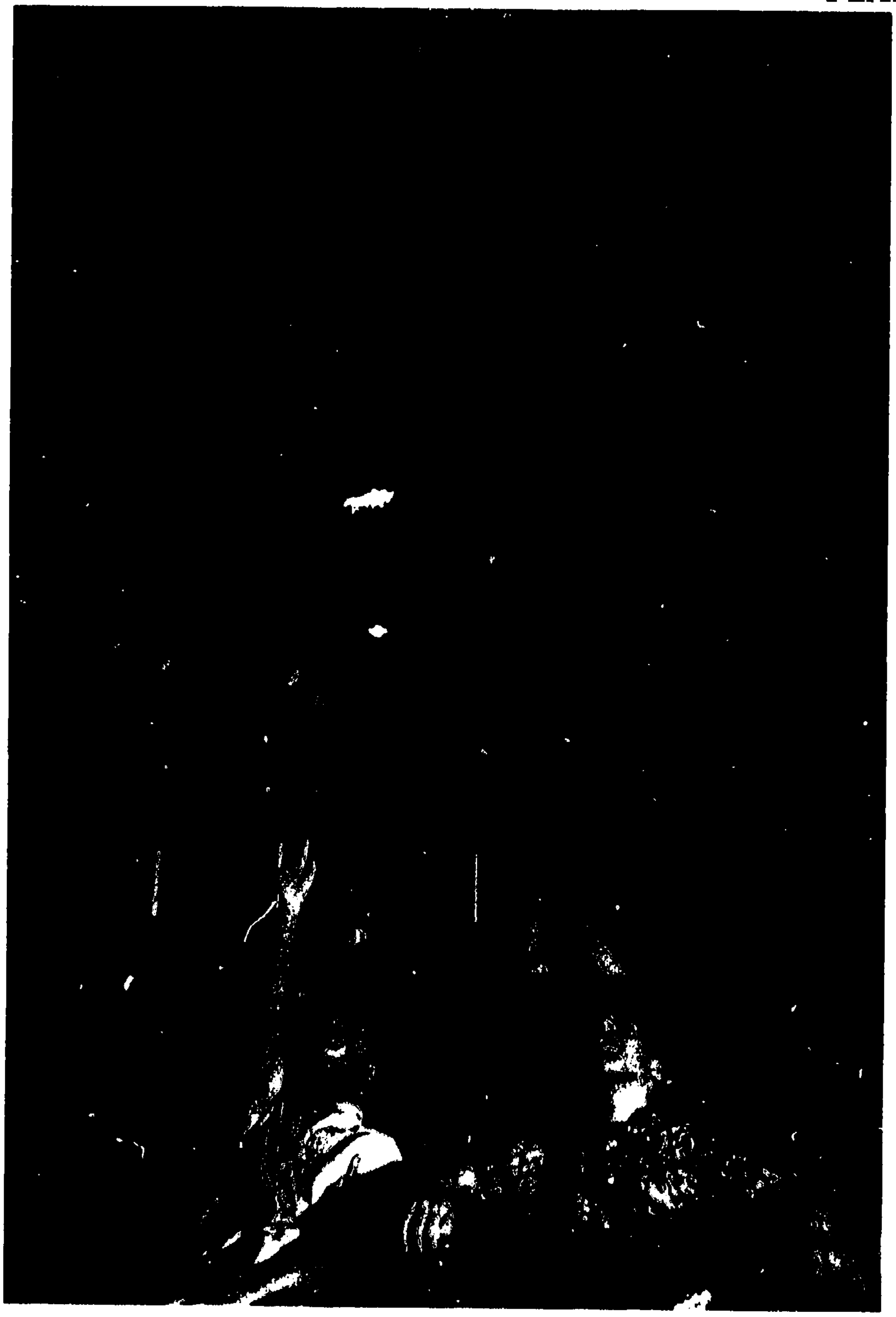
Society for Crippled Children, 2800 Thirteenth Street, NW, Washington, DC 20009.

U.S. Department of Education, Bureau of Education for the Handicapped, 400 Maryland Avenue, SW, Washington, DC 20202.

School Science Facilities 6

> *"I am among those who think that science has great beauty. A scientist in his laboratory is not only a technician: he is also a child placed before natural phenomena which impress him like a fairy tale."*
> — **Marie Sklodowska Curie**

ELEMENTARY SCHOOL FACILITIES
Self-Contained Classrooms
Science Classrooms or Centers
A Look to the Future
SECONDARY SCHOOL FACILITIES
Laboratories
Planning for the Future
PLANETARIUMS IN CONNECTICUT



The facilities required for the science program are as limitless as a teacher's imagination and budget. Obviously, it is impossible to anticipate the diversity that occurs. However, there are several common elements needed to conduct an efficient activity-centered program in any school. Regardless of the science program implemented, it is desirable to make the facilities as flexible as possible. They should accommodate large- and small-group instruction, independent study activities and, to the extent possible, anticipate the changes necessitated by a curriculum of science evolving toward the future.■

ELEMENTARY SCHOOL FACILITIES

Realizing the financial stress that new curriculums and associated facilities put on the budget of a school system, many of the newer curriculums for the sciences are designed to function within existing education environments. In the public schools of Connecticut, the K-5, K-6 or K-8 sequence is used in approximately two-thirds of the elementary schools, with the majority following a K-6 structure. Since the K-6 program predominates at the national level, elementary science curriculums often have been organized around this K-6 core.

Most of the programs assume that elementary school teachers are not science specialists and that they teach in self-contained classrooms. Science usually is taught in an elementary classroom and is structured around intraclass activities performed by individuals or small groups. The science units and individual lessons are developed around common materials which do not require unusual or elaborate equipment. Therefore, a teacher or assistant can assemble the necessary learning materials from local sources in the community or the surrounding area. It also is possible to purchase kits or prepared lessons from the various educational supply houses. The advantage in the commercially packaged units is that less time is required to gather materials. Most units come in their own containers which are suitable for classroom storage.

Science should be an integral part of the elementary school program. The materials and activities should not be isolated from normal class activities. However, the classroom should provide the following: a section for storage of nonperishable substances; an area exposed to sunlight; facilities for animals required for extended observations; a work area for students to do individual or personalized science activities; an area allocated for the retention of experiments that extend over several days; and means for obtaining and discarding water. Any experiments requiring electricity, such as in the Elementary Science Study (ESS) unit, "Batteries and Bulbs," can use common batteries or dry cells. In units needing heat, candles or flat-top hot plates can be used. Once these preliminary materials are obtained, the room will be equipped to provide a continuing program regardless of the curriculum.■

Self-Contained Classrooms

In schools where the classrooms are self-contained, Figure 1, Possible Classroom Arrangement For Science, suggests one arrangement of the facilities for carrying on the elementary science program.

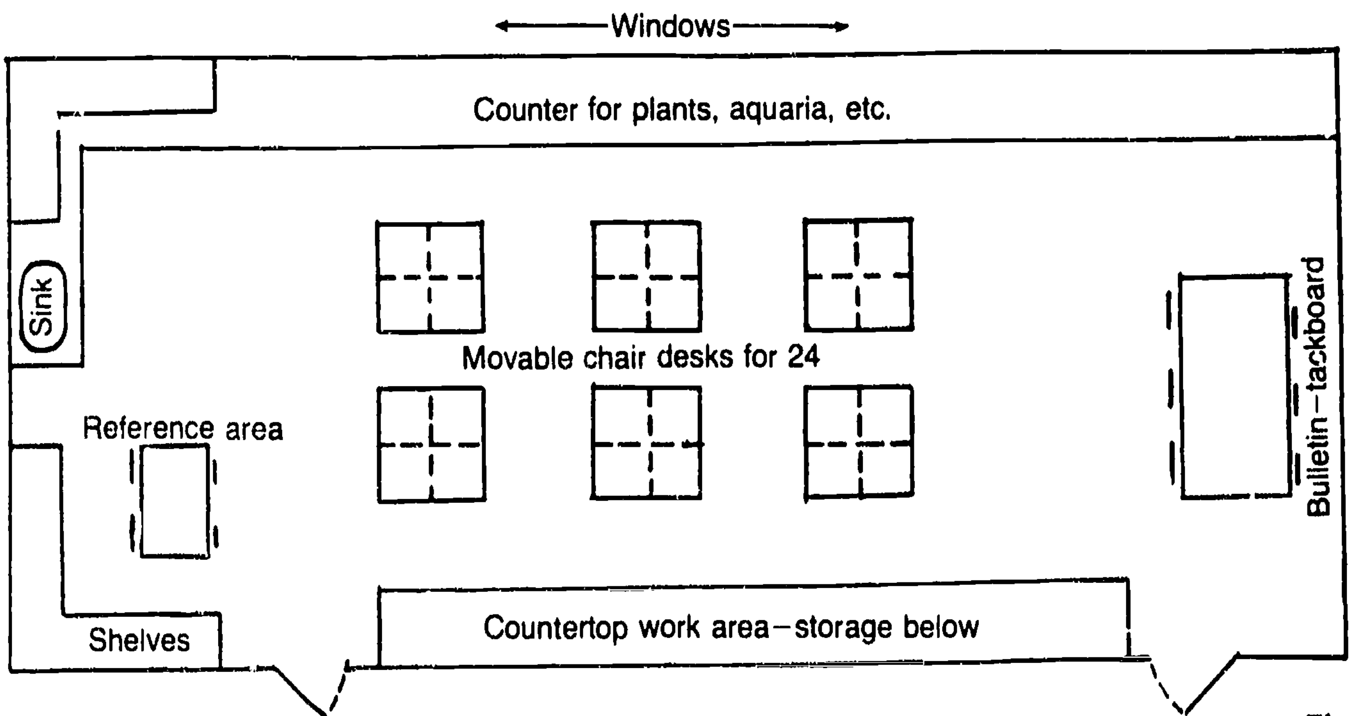


Figure 1
Possible Classroom Arrangement For Science

When school systems allocate specific segments of the day for science, the entire classroom quickly can be restructured to meet the needs of the particular lesson, but when the curriculum is structured around the open-class concept, space requirements are substantially increased. Facilities must continuously provide a diversity of readily accessible lessons; work areas that range from desktops to sinks; several disposal areas appropriate for waste materials; and the organization to meet the demands of fluctuating numbers of students engaged in a variety of science investigations, all at different stages of completion.■

Science Classrooms Or Centers

One disadvantage in using the typical elementary classroom is the difficulty in conducting individualized or personalized experiments. To provide greater attention to the science program and for individualization, a growing number of schools have adopted a science program under the guidance of a science coordinator, consultant or resource person. This individual can direct a science center with the assistance of other members of the staff.

An alternative is to have the science resource person use the teacher's room for the various lessons and the center for special activities. The center itself may be an area used primarily for consolidation of materials and equipment and the dissemination of packaged units for daily or weekly use. It also may be a work area containing electrical, gas and water outlets.

Along with these facilities, there usually is sufficient table space and room for several diverse activities to be conducted simultaneously. The science center has other advantages in that it can provide an opportunity for students to conduct experiments without disturbing other students. The center could be open on a continual basis, enabling students to do experiments during the day as their schedules permit. Figure 2 (Possible Floor Plan For A Science Center) provides one means of organization.

A science center enables a school system to purchase materials for a particular curriculum without duplicating units for every classroom. Some centers contain room for activities from the newer curriculums to further stimulate personalized science investigations.

In an attempt to use many forms of learning experiences, some school districts have established learning centers with a nucleus consisting of a library and reference area as shown in Figure 3 on page 48 (Learning Center With Library As Nucleus). The science facilities contain all the advantages of a science center, and audiovisual and other materials are easily accessible without taking up valuable laboratory space. The learning center also enables students to conduct investigations in one area and quickly go to another room or center for supplementary information or materials.■

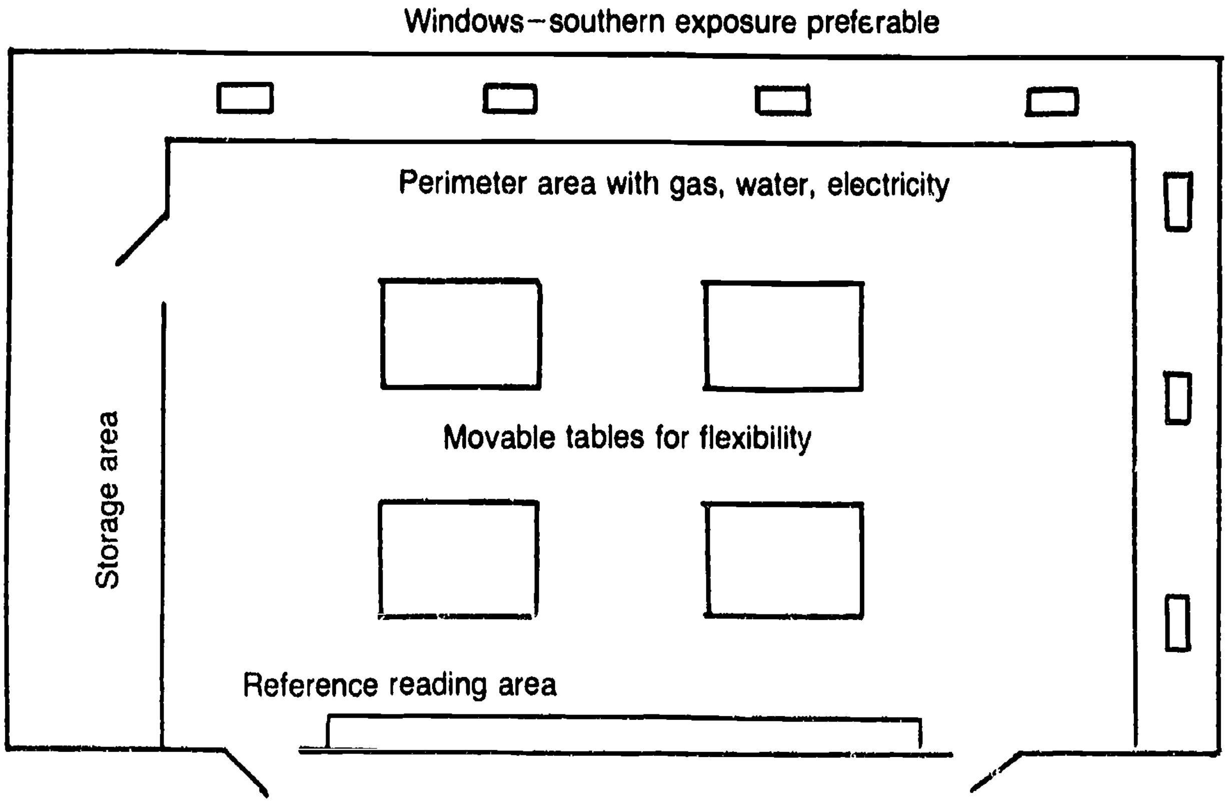


Figure 2
Possible Floor Plan For A Science Center

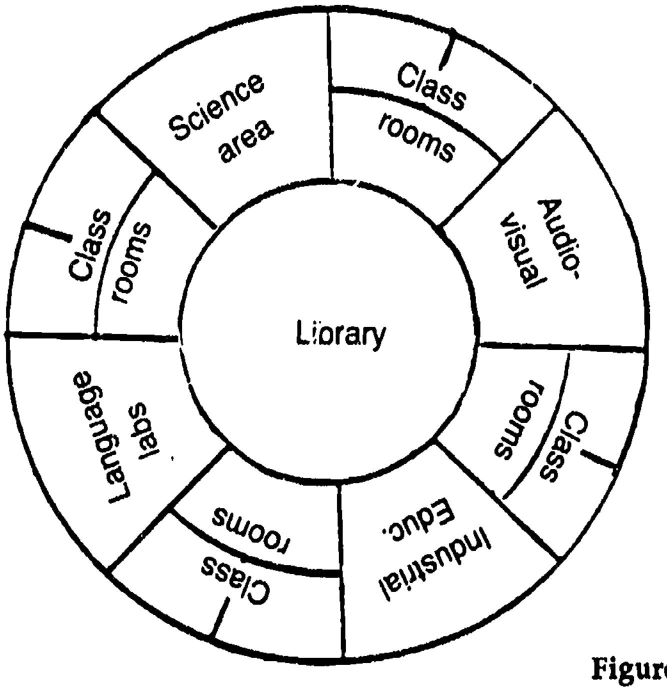


Figure 3
Learning Center With Library As Nucleus

A Look To The Future

The use of new forms of technology is having an effect on the design of classrooms. One design for an elementary science center arrangement appears in Figure 4 (New Designs For Elementary School Science And Health). This design, developed by and used with the pemission of the Biological Sciences Curriculum Study Group and IBM, provides space for science investigations as well as workstations for computer and laser disk use. There undoubtedly will be other arrangements proposed in the next few years.

In light of the many new science curriculums, it is important that facilities in elementary schools be made available to accommodate them. These facilities will depend upon the philosophy of the school and its approach to instruction.■

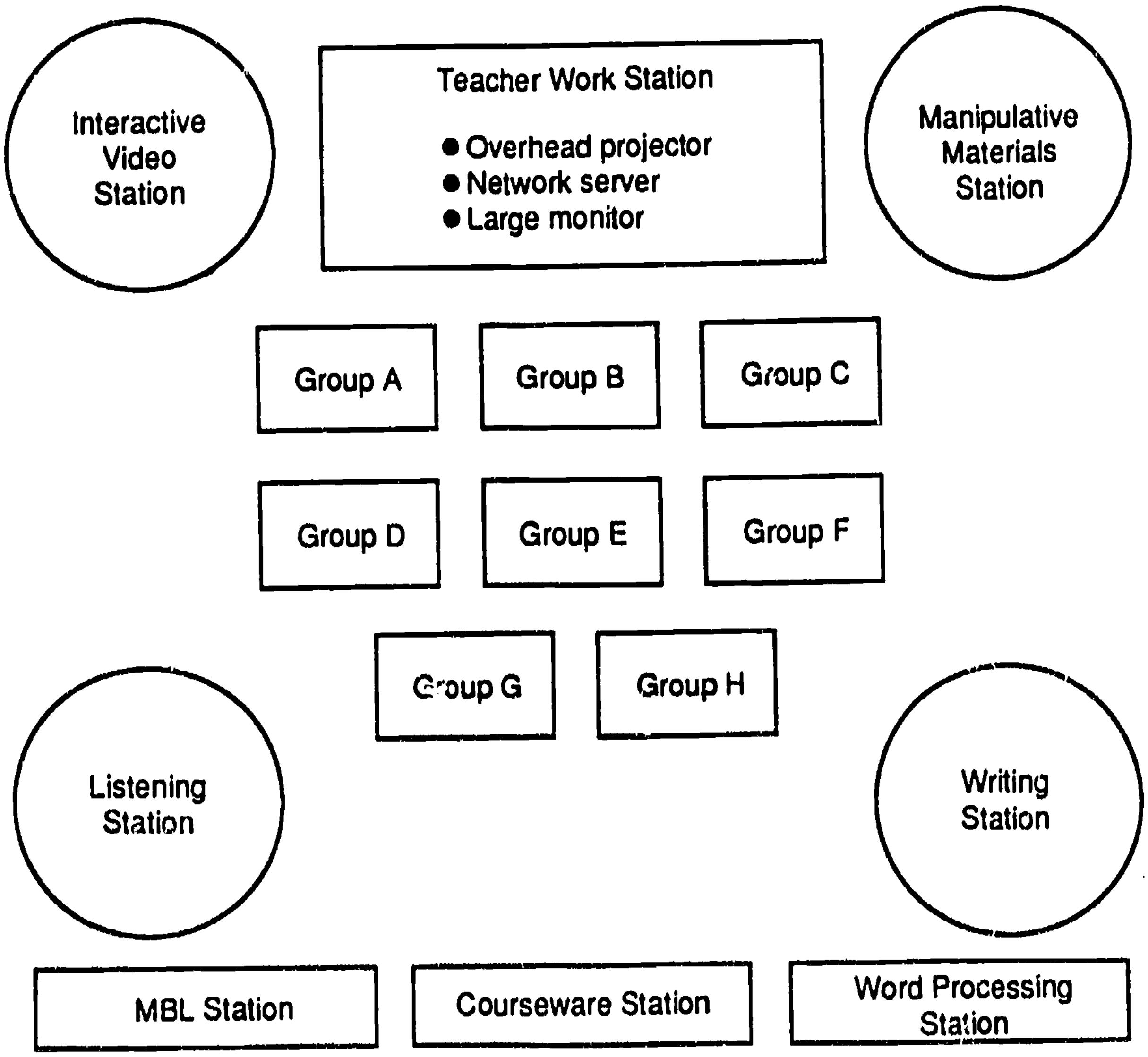


Figure 4
New Designs For Elementary School Science And Health

SECONDARY SCHOOL FACILITIES

There are certain considerations to keep in mind when planning high school science facilities.

Flexibility. Science facilities should be planned for the existing curriculum but with sufficient flexibility to meet the needs of the future. Multipurpose labs and flexible, movable lab tables and benches are preferable to massive, stationary lab furniture. For recommendations on buying furniture and laboratory tables and benches, persons should contact their school district's purchasing agent.

Room size. Room size should be variable and planned for a wide range of activities from seminar-type rooms accommodating 5 to 10 students to large lecture or activity rooms seating 100 to 150 students. Availability of space for individual work or long-term projects is desirable.

Storage facilities. Centralized storage facilities are quite common in newer buildings. Laboratory assistants or technicians may work in this area to supply the needs to all labs and individual student projects. In designing the science area, decentralized storage facilities may provide advantages by lessening the movement of apparatus and equipment. An adequately ventilated central storage area also is desirable. Because of the convenience factor, storage spaces between science rooms should be considered. Open shelving, rolling carts and racks are handier and less expensive than enclosed cupboards and cabinets.

Specialized rooms. Plant rooms, animal rooms, self-study carrels and independent study areas are desirable features to be incorporated in new science rooms. In-room library areas with magazines and reference materials can be designed to make these materials readily available.■

Laboratories

The possible arrangements for laboratory layouts are practically endless. However, most laboratory arrangements follow three general patterns. These are the perimeter, the island, or the long, straight-table type. Each style has certain advantages and should be studied carefully before making a final selection. However, in accordance with National Science Teachers Association (NSTA) guidelines, it is recommended that there be a minimum of 45 square feet (5.5 square meters) per student in a classroom laboratory.

The perimeter layout locates the laboratory work space around the walls of the room. This may be a straight-table type or there may be tables placed perpendicular to the walls to give additional space. Water, gas and other desired services are available to all stations.

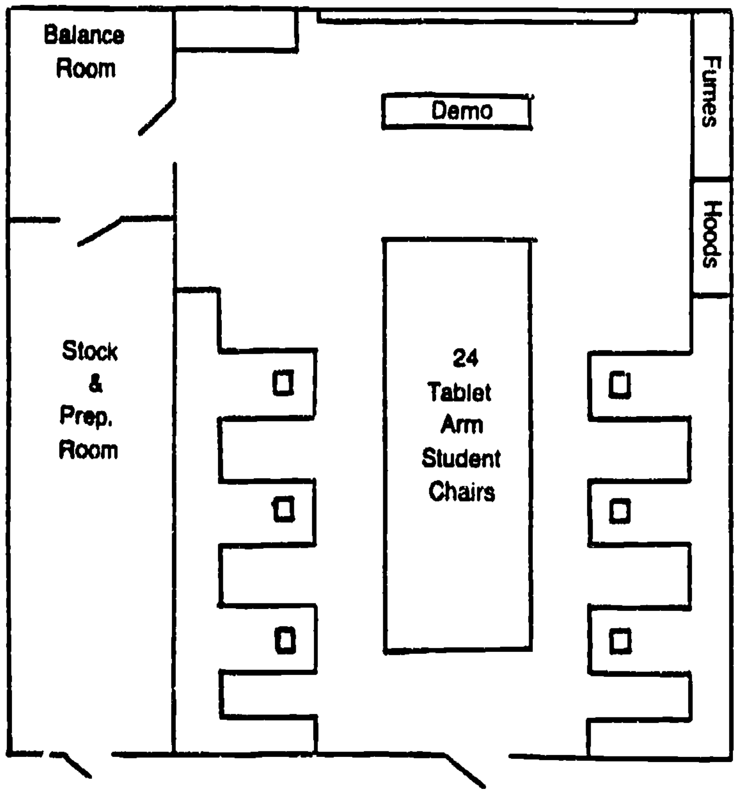


Figure 5
Typical 24-Student Chemistry Laboratory

With movable tables or tablet arm chairs in the center of the room, this setup has much flexibility for varied activities (see Figure 5, Typical 24-Student Chemistry Laboratory).

The island type of laboratory space may have rectangular, square or octagonal-shaped tables. These may be serviced from an island which is permanently (or in some new laboratories, temporarily) located in the room, but the tables are movable so that different arrangements are possible. A separate area is available for tables or chairs for nonlaboratory activities.

The long, straight-table type laboratory bench with service pipes and trough sinks running the length of the table to service students on both sides of the bench is the style most common for many years. There is little flexibility to this setup and it is not often seen in newer buildings.

Biology laboratories are commonly of two different types. One type utilizes long tables with sinks and facilities in the middle. The students sit on stools running along the sides of the table (see Figure 6 on page 50, Typical 24-Student Biology Laboratory). A modified perimeter arrangement also is used (see Figure 4 on page 48). Either 30-inch (.76m) desktops using standard-height chairs or 36-inch (.91m) tabletops with stools are used.

Types of lab activities. Some laboratory activities are best accomplished with the student seated at a standard table with a height of 30 inches (.76m). Many biology experiments use this table height. Most chemistry experiments are performed with the students standing at a bench with a height of 36 inches (.91m). Stools or

chairs and tables or islands of the proper height give great flexibility for sit-down activities.

Lecture labs vs. separate labs. It is well established that science courses should be laboratory oriented. Many chemistry, physics and biology courses meet for four or five lecture periods and one double period for laboratory each week. In the newer programs, laboratory activities may be conducted three or four times a week, a schedule requiring that they be possible on any day the class meets. In situations where a laboratory is shared by teachers, this flexibility is not available.■

Planning for The Future

A typical junior high school with Grades 7-9 will offer three years of science to all students. The courses probably will be a life science course, a physical science course and a course in earth science. The high school with Grades 10-12 probably will offer biology, chemistry and physics with various high and low sections, and possibly advanced placement courses. There is a trend to offer courses in ecology, oceanography, meteorology and some other specialized areas.

Microcomputer-based science laboratories. With the increase in use of microcomputers in the laboratory, and other forms and uses of technology such as laser disk, CD-ROM or networking, it is important to keep in mind that approaches to instruction in science are undergoing changes. At present, six microcomputers per laboratory (one per four students) is a useful guideline. However, optimum figures remain to be determined as more experience is gained.

Planetariums. A number of schools now have planetariums. These facilities also can be provided on a regional or a local basis through the use of state and federal assistance. Unlike some of the school facilities mentioned previously, the planetarium has the advantage of being applicable through the entire science program, K-12. At the primary level, the planetarium serves to simulate astronomical phenomena without the reliance on hours of observations. Actual measurement and recording of data can promote simultaneous growth in mathematics. Since most planetariums serve an entire system or region, they are rarely unoccupied. A list of some of Connecticut's planetariums is provided at the end of this chapter.

Computer centers. Computer science at the K-12 level is in its infancy, but there are new computer programs being developed in all branches of science. Besides responding to the obvious need for anyone interested in a career in science to understand computers, the facilities provide a nucleus for interdisciplinary studies with mathematics, business and other subjects.

New facilities. In planning new science facilities, a 5- or 10-year projection is desirable. It is useful to visit as many schools as possible that are known to have exemplary science facilities. The State Department of Education can furnish information on specific examples. Laboratory furniture companies also have designs for various kinds of science facilities. District officials should discuss the science program needs with teachers in various schools and with architects known for designing and building good facilities. The time involved will be well spent and will result in better-designed science facilities that will be functional for many years to come.■

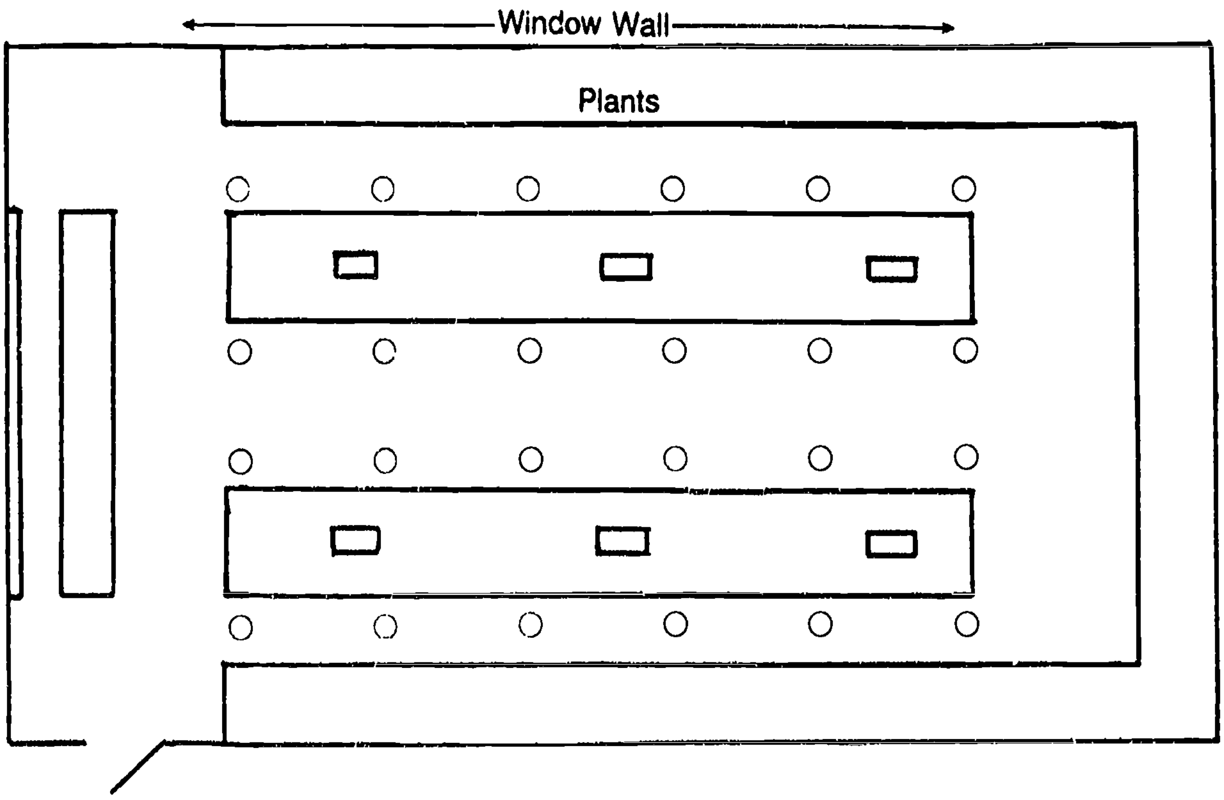


Figure 6
Typical 24-Student Biology Laboratory

PLANETARIUMS IN CONNECTICUT

Bridgeport

Henry B. DuPont III Planetarium
Museum of Art, Science and Industry
4450 Park Ave., Bridgeport, CT 06604
(203) 372-3521
Est. 1962; 10 M. Dome, 125 seats
projector type, Spitz-512

University of Bridgeport Planetarium
285 Park Ave., Bridgeport, CT 06602
(203) 576-4271
Est. 1971; projector type, V Apollo

Danbury

Western Connecticut State University Planetarium
181 White St., Danbury, CT 06810
(203) 797-4218
Est. 1960; 8 M. Dome, 48 seats
projector type, S 373 + AZ

East Lyme

East Lyme High School Planetarium
Chesterfield Road, East Lyme, CT 06333
(203) 739-6946
Est. 1972; 7 M. Dome, 49 seats
projector type, S 3 AP

Enfield

Enrico Fermi High School Planetarium
North Maple Street, Enfield, CT 06082
(203) 741-3551, Ext. 275
projector type, S A4

Glenville

Glenville Elementary School Planetarium
33 Riversville Road, Glenville, CT 06830
(203) 531-9287
Est. 1974; 5 M. Dome, 25 seats
projector type, S 373

Hartford

Hartford Public High School Planetarium
55 Forest St., Hartford, CT 06105
(203) 278-5920
Est. 1963; 7 M. Dome, 60 seats
projector type, S A3PR

Meriden

Meriden Science Trailer Planetarium
John Barry School, Meriden, CT 06450
(203) 237-8831
3 M. Dome, 20 seats
projector type, Nova

Milford

Joseph A. Foran High School Planetarium
Foran Drive, Milford, CT 06460
(203) 783-3501
Est. 1973; 9 M. Dome, 70 seats
projector type: Goto GX10
Observatory: 15 cm. Refractor
8 cm. Prominence Viewer

Mystic

Seaport Planetarium, Mystic Seaport, Inc.
Mystic, CT 06355
(203) 536-2631
Est. 1960; 9 M. Dome, 100 seats
projector type, S A2

New Britain

Copernicus Hall Planetarium
1615 Stanley St., New Britain, CT 06050
(203) 827-7419
Est. 1974, 11 M. Dome, 115 seats
projector type S 512

New Canaan

New Canaan High School Planetarium
Farm Road, New Canaan, CT 06840
(203) 966-9538
Est. 1971; 9 M. Dome, 60 seats
projector type, S A4

New Haven

Southern Connecticut State University Planetarium
501 Crescent St., New Haven, CT 06515
(203) 397-4293
Est. 1958; 7 M. Dome, 80 seats
projector type, S A1

New Milford

New Milford High School Planetarium
Sunny Valley Road
New Milford, CT 06776
(203) 354-3936
Est. 1970, 5 M. Dome, 25 seats
projector type. V EROS

Norwich

R. B. Oliver Planetarium
Roton Middle School
Highland Avenue, Norwalk, CT 06854
(203) 852-9874
Est. 1967; 7 M. Dome, 60 seats
projector type, A3PR

(continued)

Stamford
Edgerton Memorial Planetarium
39 Scofieldtown Rd., Stamford, CT 06903
(203) 322-1645
Est. 1957; 8 M. Dome, 50 seats
projector type, S A1
Also: research observatory

Storrs
University of Connecticut Planetarium
Physics Department, Storrs, CT 06268
(203) 486-4915
Est. 1956; 5 M. Dome, 25 seats
projector type, S A2

Trumbull
Hillcrest Planetarium
Hillcrest Middle School
530 Daniels Farm Road
Trumbull, CT 06111
(203) 452-5163
Est. 1967; 10 M. Dome, 80 seats
projector type, S A3P

Wallingford
Mahan Planetarium
Sheehan High School
Hope Hill Road, Wallingford, CT 06492
(203) 294-5900
Est. 1971 9 M. Dome, 63 seats
projector type S A4

Washington
Shepaug Valley Middle and High Schools
South Street, Washington, CT 06793
(203) 868-7326
Est. 1972-76; 6 M. Dome, 30 seats
projector type, Nova III

West Hartford
Gengras Planetarium
950 Troutbrook Drive
West Hartford, CT 06119
(203) 236-2691
Est. 1968; 12 M. Dome, 149 seats
projector type, S SIP

Willimantic
Robert K. Wickware Planetarium
Eastern Connecticut State University
Willimantic, CT 06226
(203) 456-2231
Est. 1972; 9 M. Dome, 60 seats
projector type, S A4

Windsor
Chapin Planetarium, Loomis Chaffee School
Batchelder Road, Windsor, CT 06095
(203) 688-4934
Est. 1959; 6 M. Dome, 50 seats
projector type, S A3P

Science And Safety 7

> *"Although this may seem a paradox, all exact science is dominated by the idea of approximation."*
> – Bertrand Russell

Responsibilities of the Teacher
Safety Equipment
Chemical Purchase, Storage and Disposal
School Safety Programs
Sources of Information

To provide a safe and appropriate environment for learning is the task of every teacher, but this responsibility holds particular concern for the science teacher. Science is best learned by doing, and doing involves a risk of injury.■

Responsibilities of the Teacher

The science teacher's responsibilities begin with a duty to offer proper instruction for students. In a laboratory situation this requires careful attention to the use of safe methods and materials. Proper procedures for the handling of supplies and equipment should be taught in a planned, formal lesson and reinforced as laboratory activities are conducted. Most commercially available laboratory manuals contain safety rules which may be a part of the safety program.

Directions for laboratory activities should be written, with the instructor reviewing the directions with students before the experiment is begun. In discussing the activity, the teacher should call students' attention to procedures to be followed and to the materials that, if misused, could prove hazardous. Particular attention should be paid to class-related activities of students outside the classroom. Teachers must provide appropriate instruction for students working on projects for science fairs or other related activities. It is important to remember that teachers must serve as models who follow appropriate safety rules and procedures, since students will look to them to determine how to behave correctly in a laboratory situation.

A second responsibility of the teacher is adequate supervision. A laboratory is a potentially dangerous environment, requiring particular attention on the part of the instructor. Lessons in laboratory safety should emphasize appropriate student behavior in laboratory situations. Students should never be permitted to work unsupervised in the laboratory. If an emergency requires that the teacher leave the class, competent coverage must be provided.

It is recommended that short-term substitute teachers not be permitted to conduct laboratory activities. If an extended teacher absence requires that laboratory work be continued, the substitute teacher should have appropriate certification and experience in laboratory situations.

Since maintenance of a safe laboratory environment is an important responsibility of the science teacher, it is strongly recommended that the teacher not be required to supervise more than 24 students in a laboratory activity. If this occurs, the teacher should call the supervisor's attention to class size problems.

The physical design and condition of the laboratory are additional concerns. Adequate ventilation, provision for secure storage of materials, and the proper functioning of laboratory equipment are particularly important.

At the elementary school level, science often is taught in classrooms not designed for science laboratory activities. It is particularly important that the design of the classroom and the facilities within it be taken into consideration when conducting science investigations. Elementary school teachers of science should be fully aware of the safety aspects of the use and storage of the chemicals they are using. They also should be well versed in the safety and humane aspects of animal handling as well as the safety issues relating to the materials they are using in the life, physical and earth sciences.■

Safety Equipment

The use of appropriate eye protection is mandated by Section 10-214a of the *Connecticut General Statutes*. State agency regulations specify that the wearing of splash-proof goggles is required whenever caustic or explosive chemicals, hot liquids, solids or gases are used. Safety shields should be available for use in teacher demonstrations. The Occupational Safety and Health Administration (OSHA) requires the presence of eyewash fountains or safety showers. Eye protection mandates authorized under Section 10 – 214a of the Regulations of Connecticut State Agencies follow:

> **Section 10 – 214a – 1. By whom, when and where eye protective devices shall be worn: definitions.** Any person who is working, teaching, observing, supervising, assisting in or engaging in any work, activity or study in a public or private elementary or secondary school laboratory or workshop where the process used tends to damage the eyes or where protective devices can reduce the risk of injury to the eyes concomitant with such activity shall wear an eye protective device of industrial quality in the manner in which such device was intended to be worn. For the purposes of Sections 10 – 214a – 1 to 10 – 214a – 3, inclusive, "workshop" and "laboratory" shall include any room or area used to teach or practice industrial arts, vocational and technical education; science, arts and crafts, or any similar skill, activity or subject. The following list of sources of danger to the eyes and type of protection required to be worn in each case is exemplary, not exclusive:

Source of Danger to the Eyes		Type of Protection Required
(a)	Caustic or explosive chemicals	Clear goggles, splash proof
(b)	Explosives, solids or gases	Clear goggles
(c)	Dust-producing operations	Clear goggles, splash proof
(d)	Electric arc welding	Welding helmet
(e)	Oxy-acetylene welding	Colored goggles or welding helmet
(f)	Hot liquids and gases	Clear goggles, splash proof
(g)	Hot solids	Clear or colored goggles or spectacles
(h)	Molten metals	Clear or colored goggles
(i)	Heat treatment or tempering of metals	Clear or colored goggles
(j)	Glare operations	Colored spectacles or goggles or welding helmet
(k)	Shaping of solid materials; chipping, cutting, grinding, milling, sawing, stamping	Clear goggles or spectacles
(l)	Repairing or servicing of vehicles when hazard is foreseeable	Clear goggles or spectacles
(m)	Spraying and dusting	Clear goggles, splash proof
(n)	Other similar activity being conducted in the instructional program which risks damage to the eyes	Proper eye protective device

Section 10 – 214a – 2. Minimum standards for the design, construction and quality of eye protective devices used in schools. Any eye-protective device used in such school workshops or laboratories shall be designed and constructed to resist impact, provide protection against the particular hazard for which it is intended, fit snugly without interfering with the movements of the user and be durable, cleanable, and capable of frequent disinfection by the method prescribed for such device by the school medical adviser. All materials used in such eye protective devices shall be mechanically strong and lightweight, non-irritating to perspiring skin and capable of withstanding washing in detergents and warm water, rinsing to remove all traces of detergent and disinfection by methods prescribed by the school medical adviser without visible deterioration or discoloration. Metals used in such devices shall be inherently corrosion resistant. Plastics so used shall be non-flammable and shall not absorb more than five per cent of their weight in water.

Section 10–214a–3. Responsibilities of public and private elementary and secondary school governing bodies. The governing board or body of each public and private elementary and secondary school in the state shall require the use of appropriate eye protective devices in each laboratory and workshop by any person in such areas during any activity engaged in, and shall post warnings and instructions in laboratories and workshops which include the list of hazards and protection required set forth in section 10 – 214a – 1. Such boards shall make and enforce rules for the maintenance of all eye protective devices in clean, safe condition and shall replace any such protector which becomes irritating to the skin.

Fire extinguishers and fire blankets should be a part of the basic equipment of every laboratory. The local fire marshal can be a source of information as to the appropriate type and placement of extinguishers. State and local codes will dictate the presence and location of shut-off valves for gas, electricity and water in the laboratory.

Materials for the containment and clean-up of chemical spills should be readily available. Commercial spill kits may be purchased from most school laboratory supply companies. Each school district's purchasing agent will be able to provide the names of companies specializing in safety equipment and supplies. Also, the National Science Teachers Association publishes a document containing the names of suppliers of safety equipment and materials (see Resources at end of chapter).

Laboratory aprons or coats should be worn routinely in the laboratory. Specialized situations may require the use of gloves; however, it should be noted that gloves are designed for use with specific chemical reagents and their intended use should be determined before their purchase.

A first-aid kit of basic supplies is recommended. Teachers or staff members who administer emergency treatment are protected from civil damages for ordinary negligence if they have satisfactorily completed a course in first aid with a local health department or with one of several organizations, such as the American Red Cross.■

Chemical Purchase, Storage and Disposal

While some element of risk is inherent in most laboratory activities, the responsibility of assessing the hazards and usefulness of chemical reagents is of particular concern to the teacher. The Council of State Science Supervisors, in *School Science Laboratories: A Guide to Some Hazardous Substances* (1984), has identified chemicals requiring particular care in handling, storage and/or disposal. The *Manual of Safety and Health Hazards in the School Science Laboratory* of the National Institute for Occupational Safety and Health (1984), lists "Substances with Greater Hazardous Nature than Potential Usefulness." This same manual discusses safety concerns associated with experiments commonly found in chemistry, physics, earth science and biology courses. However, the teacher is advised to consult professional literature on a regular basis in order to ensure that information is both current and correct. Chemicals which have been used routinely in school laboratories have been later determined to present health hazards.

The Material Safety Data Sheets which chemical suppliers are required to provide with each chemical purchased are an additional source of information. These data sheets contain physical property data, toxicological information, hazard alerts, reactivity data, spill and disposal procedures, and storage and handling precautions.

The storage of chemical reagents is closely related to the safe and appropriate use of chemicals. Security is a vital element of storage. Storage rooms and cabinets should be kept locked. The storage of chemicals in classrooms is inappropriate.

While the alphabetical arrangement of chemicals is convenient, it may result in incompatible chemicals being placed in close proximity to one another. Recommended storage patterns may be found in the Council of State Science Supervisors' manual. The Connecticut State Department of Education's *Fire Safety and Prevention Manual* (1976), provides extensive information on reagent hazards.

The U.S. Environmental Protection Agency has identified reagents which present specific risks to the environment. It has specified procedures for the disposal of these reagents. Chemicals identified as hazardous must be disposed of in licensed landfills, and must be transported to these landfills by licensed disposal services. The Connecticut State Department of Environmental Protection maintains lists of licensed waste handlers.

Since the cost of disposing unwanted chemicals can be considerably greater than their purchase price, the teacher is advised to become familiar with disposal requirements before chemicals are purchased. For reasons of health, safety and economy, the maintenance of a current chemical inventory should be an integral part of laboratory practice. A copy of the inventory should be available to school authorities, and the location of hazardous and flammable chemicals should be noted. A list of state-licensed disposal companies is available from the Connecticut State Department of Environmental Protection.

All utilities, such as gas, electricity and water, should be kept up to code. Students should be instructed in the use of the outlets for these utilities, with particular emphasis on the dangers of misusing them.■

School Safety Programs

Science safety should be the concern of everyone – teachers, administrators, staff members, supervisors and students. The development of a formal program of safety practices and procedures should include training for teachers and administrators in programs such as "Safety in the School Laboratory," developed by the Council of State Science Supervisors and the National Institute for Occupational Safety and Health. The training of all teachers of science in appropriate safety procedures and the use of laboratory equipment should be a high priority for any school.

While training in safety can be the beginning of a personal commitment to safe practices, the formation of a school safety committee should be the beginning of a schoolwide focus on safety needs. Composed of representatives of administration, students, and the teaching and support staffs, the committee should be responsible for regular examinations of laboratory and storage facilities to assure that these facilities meet established safety guidelines. The committee should develop a plan for

teaching safety, for evaluating procedures followed in laboratory activities, and for communicating to appropriate authorities the need for new or improved facilities, equipment and procedures.■

Sources of Information

The guidelines offered in this chapter serve as an introduction to the topic of school science safety. References and resources at the end of the chapter include some science safety guides that will help both the administrator and the teacher to develop, implement and evaluate plans for science safety. Personnel from the Connecticut State Department of Education, the U.S. Consumer Product Safety Commission, the National Institute for Occupational Safety and Health, the Connecticut State Department of Environmental Protection, and local health and fire officials can serve as resources for the development of a total program of laboratory safety.■

References

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Council of State Science Supervisors. *School Science Laboratories: A Guide to Some Hazardous Substances.* Washington, DC: U.S. Consumer Product Safety Commission, 1984.

U.S. Department of Health and Human Services; Berberich, NJ, et al. *Manual of Safety and Health Hazards in the School Science Laboratory.* Lancaster, VA: Council of State Science Supervisors, 1984.

Resources

American Chemical Society, 1155 16th Street, NW, Washington, DC 20036. *Chemical Risk: A Primer; Safety in Academic Chemistry Laboratories; Hazardous Waste Management* and *Health and Safety Guidelines for Chemistry Teachers.*

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National Academy Press, 2101 Constitution Avenue, NW, Washington, DC, 20418. *Prudent Practices for Handling Hazardous Chemicals in Laboratories.*

National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

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National Institute for Health, NIH Publication 85-23, Room B3BN10, Building 31, Bethesda, MD 20205, *Guide for Care and Use of Laboratory Animals.*

National Science Teachers Association. *Safety in the Elementary Science Classroom* (1978) and *Safety in the Secondary School Classroom and Laboratory* (1986), 1742 Connecticut Ave., N.W., Washington, DC 20009.

National Science Teachers Association. *Science Education Suppliers, 1989.* NSTA, 1742 Connecticut Ave., N.W., Washington, DC 20009.

Occupational Safety and Health Administration (OSHA) Area Office, 450 Main St., Hartford, CT 06103.

Sax and Lewis, Van Nostrand-Rienhold Co., 115 Fifth Avenue, New York NY 10003, *Rapid Guide to Hazardous Chemicals in the Workplace.*

U.S. Consumer Product Safety Commission, 6 World Trade Center, New York, NY 10048. *School Science Laboratories: A Guide to Some Hazardous Chemicals.*

Instructional Materials And Technology 8

"There is opportunity enough for anyone prepared to do what the world needs done."
– George Washington Carver

There is a tremendous wealth of science instructional materials and technologies available to teachers today. In addition to the more traditional textbooks and laboratory equipment, many current technological devices such as interactive television, calculators, computers and laser disks are adaptable as aids to learning and experimentation in the sciences. A major challenge for teachers of science is the selection and effective use of the available materials and techniques for the programs or courses being taught.

In the past decade, inflationary increases in the costs of textbooks, science supplies and equipment have accompanied the declining enrollment in Connecticut schools, making it more and more difficult to maintain laboratory programs. At the same time, a serious commitment to a high level of excellence in science instruction is necessary if we are to prepare students for life and work in our increasingly high-technology society. A well-functioning, well-planned, laboratory-oriented science program has the best chance of receiving the necessary financial support to keep abreast of inflation.∎

Laboratory Equipment

In the elementary school science program, simple apparatus is to be expected. Often this equipment comes packaged in classroom quantities for a particular experiment. In the middle school, junior high school and high school, as the experiments become more quantitative, the laboratory experiences require more sophisticated equipment. Graduated cylinders, centigram balances, pipettes, burettes, electrical measuring instruments, meters and gauges become more prominent. Much of this equipment is fairly expensive and some has a limited life. Long-range planning in consultation with administrators is necessary so that budgets retain the flexibility to replace broken or obsolete equipment.∎

INSTRUCTIONAL HARDWARE AND SOFTWARE

In addition to the specialized equipment for individual science courses, the hardware and software available today as supplementary teaching aids are extensive.∎

Viewing and Listening Devices

Hardware includes overhead projectors, videotape recorders, CD-ROM players, videodisc players, audiotape recorders, microprojectors, microviewers and microscopes. Many of the items are well developed, but all should be studied or previewed before purchase. Most companies offer preview opportunities. Models, slides, overhead transparencies, film loops, filmstrips and audiocassettes are available in most science subject areas. Also, the teacher may consider making his or her own audiovisual materials. Often these teacher-made resources are better adapted to the course and the expense is less than for the commercially produced materials.∎

Calculators and Computers

There is little doubt that technology will continue to play a very significant role in our society in the future. Science teachers have a major role in preparing students for this. The microcomputer of today is a powerful device that has important implications for science instruction. Further technological advances and reduced prices undoubtedly will make the microcomputer even more available to many students outside the classroom. Teachers must be ready to capitalize on access to calculators, computers and other developments in technology as these advances take place.

The low cost of calculators has made them available to the vast majority of students. In developing the local curriculum guide, there should be an indication of how and where the calculator can be used. For example, in working with general gas law in chemistry, the concept often is obscured by tedious computations. The calculator can reduce the arithmetic work so that the relationship may be better seen. Similarly, in physics, calculators with trigonometric functions can assist in the solution of problems. Programmable calculators, no longer rare, allow students to organize the problem by indicating the steps to be followed and setting the calculator to perform the calculations.

As the cost of microcomputers has dropped, they have become commonplace in the schools. The microcomputer should be looked at as a tool to assist in instructing students. It can be used in just about all subjects, but has a particularly important role in the teaching of science in the laboratory. Here the microcomputer becomes an important tool in gathering and organizing information provided by laboratory investigations. The wide number of uses to which the computer can be put makes it not only a vital but a relatively inexpensive tool for the science laboratory. Students who have access to microcomputers at home can be very helpful in assisting others in the computer's use.∎

Other Interactive Devices

Computers and other technological devices, when used to facilitate learning, sometimes are categorized as instructional technology. For example, computers are being integrated with other systems that have audio and

video capabilities. In some instances, the computer is used to program optical laser disk devices that carry large amounts of audio and video information. The computer can be used to overlay the pictures from a laser disk with drawings and textual information.

At the forefront of this approach to instruction is the incorporation of microcomputer science laboratories with laser disk devices such as the interactive laser disk and CD-ROM. In this way the student can be guided through an investigation, using the computer to store and organize data and the laser disk to provide visual information about her or his progress. Undoubtedly, new developments in this field will continue to appear, so it is important for all teachers and administrators to keep abreast of this rapidly growing and changing field.

Science teachers need to become familiar with the microcomputer and with the associated technologies. This requires a commitment to spend time with these devices and by actual use to learn their capabilities in the classroom and in the laboratory. In-service training programs which allow credit should be considered. Also, local universities that have the necessary microcomputers and associated devices to allow for a practical course often are willing to tailor a course to the specific needs of a group.

Time and again it has been said that an important purpose of a general education is to prepare students for jobs, many of which do not now exist. Whatever the future, it appears quite certain that computers and other forms of instructional technology will be important tools for learning, as well as for use in many occupations.■

Textbooks

While many schools have written curriculum guides in most subject areas, the textbook, to a large extent, determines the curriculum and the instructional patterns used.

Since the late 1950s and 1960s, science curriculum projects sponsored by the National Science Foundation in elementary and middle school science and in earth science, biology, chemistry and physics have greatly influenced the textbooks written by other authors and groups. These national projects have updated textbook material, reinforced the importance of the inquiry method of teaching, and emphasized both process and content. The subject matter has become less descriptive and more concept oriented. In addition, many supplementary materials, such as films, laboratory programs, additional readings and other materials have been made available. Most of the textbooks available in the major science subject-matter areas have been revised or new editions published over the last few years. This also is true for elementary and junior high school texts.

Textbook selection is crucial. Teachers, science supervisors and administrators usually are involved in this activity. Teachers, however, should have a major role in textbook selection, since they will be using them.■

Textbook Selection Suggestions

Since a textbook is used for approximately five years, its selection should be made with great care.

At the secondary level, an objective analysis of the text or texts should be made by a committee composed of science department members and other concerned persons such as administrators and curriculum experts. At the elementary level, as many teachers as possible, from all grades in the case of a textbook series, should be involved in textbook selection.

An evaluation checklist is helpful to focus on important aspects of a textbook. The textbook evaluation form in Appendix F contains some of the important criteria. This checklist should be used as a guide only and should be modified to serve the specific needs of the program. If, for example, laboratory activities have a high priority in the school, the rating form should be modified to give greater weight to the lab program and perhaps less emphasis on appearance, illustrations or organization.

Probably no single textbook can meet all the requirements of a school system. Therefore, the selection of supplementary texts, laboratory materials and correlated hardware and software should be coordinated with the textbook selection. The order of topics, the depth or breadth of the material covered, the extent of laboratory work and the availability of supplementary materials are some of the variables involved. Students' needs and interests and teacher expertise also are factors in the choice of the instructional materials to be acquired.■

Resources

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Science Programs And The Community 9

> *"To a person uninstructed in natural history, his country or seaside stroll is a walk through a gallery filled with wonderful works of art, nine-tenths of which have their faces turned to the wall."*
> – Thomas Henry Huxley

Planning Activities
Field Trips
Consultants and Speakers
Personal Interviews
Museums and Planetariums
Libraries
Internships in Business and Industry
Cooperative Work-Study Programs
Nature and Science Centers
Science Clubs
Assistance and Ideas
Sample Field Trip Authorization Form

Many vivid learning experiences may result from going out into the community. The field trip is one of the most common ways to extend the classroom into the community, but there are a number of others, as well. Consultants and speakers may be invited to the school to share their expertise with the students. Another excellent method to use is student observation of scientists or engineers at work. Still another is actually assisting in some of the research or development activities of practicing scientists. To the extent possible, students should be encouraged to get involved in out-of-school activities that relate to the studies they are undertaking in school. This chapter will describe a number of these activities and provide sources to contact to make use of community-based resources.■

Planning Activities

Successful school-community activities do not happen; they are planned. Detailed planning is necessary to ensure their success as a learning activity. Poor preparation may result in a slip-up that could cause the activity to fail in meeting its aims. Planning may consume almost as much time as the activity itself, but it is well worth the effort.

Any activity off school grounds must be justifiable in terms of distance, time, cost and effort. Educational efficiency is, therefore, an important consideration in the planning. One example of disregard for this criterion is the transportation of one class for a 40-minute visit to a dairy-bottling plant one and one-half hours each way.

For each out-of-school activity, the written approval of parents should be obtained. These statements should be kept on file for an appropriate period of time after the activity is undertaken. A counter-signature of the principal in addition to the teacher's signature assures the parents of administrative approval. (See page 68 for a sample field trip approval form used by the Westport, CT, schools.)■

Field Trips

Field trips often are remembered by students long after the purposes of the trips are forgotten. The field trip can bring to life what the students have only read about but never experienced. All teachers should remember that experience is the best teacher. Field trips can provide that experience.

One must remember that the fundamental objective of the field trip is to clarify or extend major concepts being studied. This is true if the trip is to the school's playing fields, the school's maintenance room or a site 150 miles away. A visit outside the classroom planned by the teacher, or by the teacher and students, allows the students to use the community as a learning laboratory. The students can explore and make observations; they can look, listen, smell and touch and, if appropriate, taste; they are able to collect information by taking notes, gathering live samples, taking snapshots and interviewing different people. Upon returning to the classroom, they can re-examine their findings. Based on the data collected, they can draw conclusions and possibly extend their experiences into new activities. A list of some 40 Connecticut field trip sites appears in Appendix H.

Caution is needed in choosing trips. Teachers should only plan excursions for their students if the visits can clarify a concept or lesson more adequately than can other learning experiences. Before taking a trip, teachers should compare its values with those of alternative experiences in order to decide which type of experience is superior. Filmstrips, films, videotape recordings, lectures, books, tape-recorded interviews and group telephone calls can be highly effective when used alone, in various combinations or as supplements to field trips.

If possible, the teacher or persons planning the trip should previsit the site for the following reasons:

- to be able to justify the trip and its potential as a learning experience;
- to become familiar with the route and the place to be visited; and
- to make sure that the trip is a safe one, e.g., in planning a visit to a factory, consider the hazards of which the students should be aware.

All precautions must be taken to ensure that the field trip is accident free. Medical histories of students must be known, e.g., possible allergies to a medical drug or bee stings. This information usually is available in the office of the school nurse. A first-aid kit is standard equipment for any field trip. If there is a student who is allergic to bee stings, the teacher should make certain that a bee sting kit is available and that someone knows how to use it.

Other information, such as the location of eating sites and comfort stations, opening and closing hours of the site, fees, tour guides and the length of travel time, can be collected during this preliminary visit.

All field trips require administrative approval (a sample authorization form is printed on page 68). Early approval will allow time for arranging necessary details. After the trip, the experience should be re-examined by the entire class. What learnings, discoveries or conclusions did the students have as a result of the trip? What other learnings or experiences should the class now pursue as a result of the field trip?■

Consultants and Speakers

Every community has individuals with expertise in the subjects or topics taught in the school system. Many of these individuals are more than willing to share their knowledge with students. A lesson or topic may be more meaningful when an expert presents a firsthand account of experiences, a working document, a piece of equipment, slides or a technique that is used in the expert's profession or field of interest.

Speakers would be used more often if teachers knew of their availability. A central catalog or file of experts who are willing to be called upon occasionally to speak to a class or group of students about a topic of interest should be established and made available to interested teachers.

A catalog of consultants may be established by having the principal, a group of principals or a committee of the parent-teacher organization send out letters and consultant forms to adult residents in the district explaining the objectives of a consultant program. If a recipient is interested in the project, he or she would complete the form, indicating the area of expertise and the age group that would benefit from a presentation.

If the school does not have a central clearinghouse system, a check may be made with colleagues about resource people who already have participated. Professional associations also have contacts with consultants and speakers throughout the state who are willing to visit schools. College and university speakers' bureaus list faculty members who are willing to share their special knowledge with members of the community. Often, a business or industry can provide a list of personnel who have expertise in specific fields.

An excellent resource which may be found in most school libraries or local public libraries is the current edition of the *State of Connecticut Register and Manual*. This reference book lists most of the state's professional societies that are concerned with specific topics such as arthritis, diabetes, cancer, heart disease, conservation, entomology and photography. Names and addresses of each society's officers are provided. These associations and clubs may be excellent resources for both teachers and students.

Once a "Guide to Speakers and Consultants" is compiled in the school, it is prudent to have someone designated to serve as curator of the guide to see that it is up-to-date. The school librarian, career coordinator, counselor or an interested parent can serve in this capacity. The publication or file may be arranged alphabetically by occupation (author, engineer, nurse, town official, etc.) or by subject (native Americans, biology of birds, ecology, space travel, etc.).

Before any speaker visits the school, the teacher should contact this person and discuss such matters as the time allotted for the presentation, the specific topics about which the class seeks information and the background of the class. The level of the presentation is of particular importance and should be appropriate for the students. The format of the presentation also should be discussed as well as the equipment the speaker may need. After the presentation, the speaker should be thanked properly. A letter from the class always is appreciated.■

Personal Interviews

There are times when a desired speaker is unable to visit the school, or feels it would be more meaningful if one or two students were to visit her or his place of work. This technique provides students with the personal responsibility for arranging and conducting the interview as well as reporting to the rest of the class.

Listed below are some guidelines for conducting a personal interview.

- Before the interview, build up a background in the content.
- Focus on the specific topic to be investigated.
- Write down specific, open-ended questions that will treat the topic thoroughly.
- Select a resource person and set up an interview time (with an alternate date "just in case") at the person's convenience.
- Send the person being interviewed a copy of the questions to be asked at least one week before the interview so he or she will be prepared.
- Plan a way to open and close the interview.
- Learn how to listen. (This is very important, even if permission is granted to tape-record the session.) If a reply is not clear, ask for clarification. Be aware of cues for drawing the interview to a close.
- Remember to thank the person interviewed, and follow up with a thank-you letter.
- Notes should be organized (the tape edited) for the report to the class. The report should be illustrated with pictures, graphs, models, charts, maps or other audiovisual aids.

A good interview requires an understanding and application of the techniques mentioned above.■

Museums and Planetariums

Today many museums are following the lead of the Science Museum of Connecticut and the Museum of Art, Science and Industry by developing hands-on activities

for their visitors. Museums such as the Connecticut State Museum of Natural History have kit-lending programs to allow students to learn about important collections.

Teachers at all levels of instruction should explore the museums within a reasonable radius of their schools in search of exhibits and other types of programs that may focus on some of the topics the class will be studying during the year. Counselors or career coordinators may be of assistance in this process.

Most communities have museums which offer visits and research opportunities to schools. The yellow pages of the telephone directory, as well as other resources mentioned previously, can furnish the names and addresses of nearby and other museums. Curators are pleased to have class groups visit their institutions.

During recent years, the field of astronomy has generated much student interest. Many students are now studying this subject. The National Aeronautics and Space Administration (NASA) has exhibitions or presentations which are offered at museums and planetariums. There are a number of planetariums in Connecticut offering programs in astronomy and relateu fields (see list at the end of Chapter 6).■

Libraries

The library is one place where students can always get assistance in their studies, projects and reports. A trip to the school or public library early in the school year will help to familiarize students with the services the library offers.

Many students may not know that films, videotapes, filmstrips, recordings, mounted pictures, slides, newspapers, pamphlets and other reference materials are available from the library. After the students have mastered the use of the school or public library, they may want to visit and use a local college or university library.

Teachers should encourage their students to apply for library cards and to use these cards frequently. Students should acquire the habit of using the library.■

Internships in Business and Industry

Many industries, town governments and places of business are willing to work with teachers and students to enrich science classes. Some are willing to offer internships to interested and able students. However, before this can take place, the school must make the initial contact with these agencies to discover what opportunities exist. Also, there are many different types of scientists who are willing and able to work with high school students.

Remember that "internship" or "shadowing" programs are different from work-study programs. Internships do not involve funds. The selected student is provided with an opportunity to work with a professional in the student's field of interest. The school makes the initial contact and provides, if necessary, the released time for the student to work in the selected facility. The student assumes the responsibility for getting to and from the plant, office or laboratory as well as all other necessary details. Recently, science centers also have helped to make these kinds of arrangements. The scientist, engineer or professor who provides this assistance often is known as a mentor.

Many benefits accrue from an internship program. One of these is the contact the school has with the local community. Another is the information the student gains about careers he or she would never obtain were it not for the experience.■

Cooperative Work-Study Programs

Cooperative work-study programs are based upon individual needs. A cooperative arrangement between school and employer to provide on-the-job experiences is developed to meet these needs. Based upon each student's abilities, there are various levels of programs. The success of these programs depends on the certified guidance person's abilities, the cooperating business or industry's attitude toward the program and the student's motivation.

These programs lead many students into as diverse a range of activities as the community can offer. Such programs help students to develop a value system and examine their own attitudes in light of society's demands in the world of work. All students, even the brightest youngsters, may benefit from internships and work-study programs at colleges, hospitals, industries and scientific laboratories.

The potential for cooperative work-study programs is enormous. Much literature, such as that available from the Bureau of Vocational Services of the Connecticut State Department of Education, should be studied before embarking upon such an effort.■

Nature and Science Centers

The Connecticut Association for Environmental Education is a network of nature centers dedicated both to the preservation and improvement of our environment and to the education of our students. Teachers, students and the general public are welcome to enjoy and utilize nature center facilities. The yellow pages of the phone book provide the names of local nature centers. A listing of some of these appears in Appendix H, Some Field Trip Sites in Connecticut.

One of the nation's outstanding science centers, the Talcott Mountain Science Center for Student Involvement, Inc., is located in Avon. This center must be visited and experienced to be fully appreciated. The Science Museum of Connecticut in West Hartford also is an excellent facility, featuring many programs for students and teachers.

Project Oceanology, a marine education program located at Avery Point in Groton, offers many programs for students and teachers from the elementary to the graduate level. The staff of this project has published an excellent series of marine education guides for use in science programs. This organization serves students and teachers in Connecticut, Massachusetts, Rhode Island and New York.■

Science Clubs

An effective means of involving students in science experiences is through science clubs. Clubs that deal with specific activities, such as radio, astronomy, computers, tropical fish and other topics, appear to be more attractive than more general science clubs.

Teachers who serve as advisors to these clubs should not assume any of the offices or responsibilities of running the club. Students should take over the club's activities as quickly as possible.

Successful science club activities often include the parent or guardian. These activities, held during nonschool hours, serve to enhance the relationship between adult and child.■

Assistance and Ideas

Within the Connecticut State Department of Education, a consultant for each discipline is available to assist teachers with problems, to answer questions and to provide information. The *Connecticut Education Directory*, published annually, contains the names and telephone numbers of the consultants and a complete listing for each school district. The science consultant may be a good source of information about learning activities outside the classroom.

The *State of Connecticut Register and Manual*, published each year, lists the various state agencies, a number of which – such as the State Department of Environmental Protection and the State Department of Health Services – may be of assistance to science teachers in planning activit .

There are many programs, both state and national, of interest to students of science. Students may enjoy science fairs, olympiads and other events that allow them to pursue their interests beyond the classroom and the laboratory. The Connecticut Science Teachers Association, through its newsletter, routinely publishes announcements of these events, some of which are listed in Appen . I, State and National Events.■

Sample Field Trip Authorization Form

Westport (CT) Schools

Instructions: Teacher to complete this form and send the entire three-part unit to principal for approval. If review by assistant superintendent or approval of superintendent is required, principal sends entire three-part unit for these approvals. Superintendent or assistant superintendent should keep last copy and return others to principal who will have teacher complete Part C.

Teacher ____________________ Grade/Subject __________ Date(s) __________

Number of Students* __________ Number of Adults* __________

School ____________________

*Legal capacity of bus is 65 occupants.

Destination ____________________ Type of trip (check one) ___ I ___ II ___ III

Date and Departure Time from (town) __________ Date and Departure Time from Destination __________ Date and Arrival Time In (town) __________

Transportation (check one)	Costs	Sources		
___ Bus	Transportation	$ ___	Cost paid by each child	$ ___
___ Train	Admission Fees	$ ___	Cost paid by other sources (specify)	$ ___
___ Car	Other	$ ___	Total pupil cost of trip	$ ___

Purpose of the trip: ____

I have reviewed the field trip policy and the procedures. I will brief students and chaperones in accordance with that policy.

____
(Teacher's Signature)

APPROVALS

1. I hereby authorize the above Field Trip.

____________________ (Signature of Principal) ____________ (Date)

Comments: ____________________

2. I hereby authorize the above Field Trip.

____________________ (Superintendent or Ass't. Sup't. whichever is applicable) ____________ (Date)

COMPLETION/FINAL ARRANGEMENTS

1. Prior to departure teacher should complete data below, keep second copy and return remainder to principal.

FINAL ARRANGEMENTS

	YES	NO
1. Permission slips for all students received?	___	___
2. Names of students going on trip submitted to office?	___	___
3. Provisions made for students not going on trip?	___	___
4. Lunchroom notified?	___	___
5. Transportation arrangements confirmed?	___	___
6. Detailed itinerary sent to parents and principals for Type II and III trips?	___	___
7. Names and telephone numbers of parents to be notified in case of accident, emergency or change of plans obtained and filed with principal?	___	___

EVALUATION AND ASSESSMENT 10

"Every tool carries with it the spirit by which it has been created... Since the measuring device has been constructed by the observer... we have to remember that what we observe is not nature in itself but nature exposed to our method of questioning."
– Werner Heisenberg

The assessment of science instruction and science programs involves the selection, collection and interpretation of information about student performance and program adequacy. Evaluation involves the use of this information to aid in making decisions about each student's understanding of the process of science and the subject matter, and about the student's competence, scientific attitudes and laboratory skills as well as his or her ability and willingness to work and learn. The total process is directed toward the improvement of the instructional process, the learning outcomes and the science program. While this chapter concerns itself primarily with the assessment and evaluation of student learning outcomes, there is reference to program assessment and evaluation as well. Among other references, the National Science Teachers Association's (NSTA) publication *Guidelines for the Self-Assessment of Secondary School Science Programs* (1978), addresses the evaluation of facilities, staff and programs.■

Assessment and Objectives

Assessment of learning outcomes begins with the establishment of broad goals which the state, district and school indicate should be achieved. Implementation of these goals means developing program objectives which state what the learner should know and do as a result of participation in the program. As indicated in Chapter 2, objectives can be stated in terms which specify what is to be achieved, by whom and under what conditions. They also can include a minimum acceptable level of learner performance. Stating objectives clearly makes it easier to devise or select ways to measure their attainment. To the extent possible, care should be taken to ensure that objectives from all levels of the cognitive, affective and psychomotor domains are included in the assessment procedures.

Science teachers need to employ both qualitative and quantitative procedures for describing and measuring learning outcomes. Some qualitative data collection techniques are behavioral and anecdotal records. These techniques are labeled "subjective" because they rely heavily on the interpretation of the individual. Sometimes they are the only feasible way of collecting certain kinds of data. However, their ultimate value may be that they give an in-depth view of the performance of the student.■

Test Instruments

Most assessments will utilize some forms of quantitative measurements. The most commonly used testing instruments are teacher-developed tests, which may be either the laboratory "practical" or paper and pencil tests.

Criterion-referenced tests. The first rule of test construction is to use student objectives as a guide in making the test. Often, the test is arranged in ascending order of difficulty with similar types of test questions grouped together. There should be questions addressing the various levels of cognitive development. If the stated objectives also indicate a performance standard such as "students will achieve a grade of 80 percent," then the test can be used for criterion-referenced purposes. Because they are designed to measure specific program objectives, criterion-referenced tests also can be very useful to the assessor in determining the success of a program. School districts may want to make use of the science objectives presented in Chapter 4 as a guide in developing their own criterion-referenced tests.

Standardized tests. There are many standardized tests which have well-developed statistics for validity and reliability and which test for everything from general academic achievement to aptitude for a subject area and specific subject knowledge. Standardized tests are designed to have the scores spread out over a wide range so that the examinees can be compared against each other. Usually standardized achievement tests are not used to show success for a program because the tests are not as useful in measuring the achievement of program objectives as are criterion-referenced instruments.

Textbook tests. Many of the program and textbook publishers supply test books which are coordinated with their materials. However, there may be a discrepancy between local program objectives and the test items. More recently, publishers have turned to a "resource book" containing many questions which meet the criteria for the various levels of the cognitive domain and which cover many student objectives. Teachers may then pick and choose those items that best fit the local objectives and thereby construct their own tests.

National tests. A number of tests are available from national sources. For example, the American Chemical Society and the National Science Teachers Association have for years cooperated to offer the *ACS/NSTA Cooperative Chemistry Test*. This is an end-of-course test offered at two levels – high school and advanced. This is a normed test which provides a percentile rating based upon a national sample of students. Similarly, end-of-course tests are available or under development in physics, biology and earth science. There are a number of commercially available tests for the elementary and middle and junior high schools which have norms developed nationally. In reviewing any tests, it is important for the teacher to make sure that the questions reflect what is being taught in the classroom.■

Connecticut Assessment of Educational Progress

The State of Connecticut has a science assessment program though its Connecticut Assessment of Educational Progress (CAEP). This test is an adaptation of the National Assessment of Educational Progress (NAEP) science section which periodically is administered in selected schools across the nation. The first Connecticut science assessment was conducted in 1974-75, the second in 1979-80 and the third in 1984-85. The Connecticut and national assessments have two major goals: to make available comprehensive data on the science education attainments of students at ages 9, 13 and 17, and to measure any growth or decline which takes place in these attainments.

Test items are designed to gather data about the knowledge, skills and attitudes of students at the specified ages. Data are reported on both the state and national tests by specified test items. Local communities using the Connecticut Science Assessment will have available data comparing their students with students in Connecticut, the Northeast and the nation.■

Self-Assessment

Another form of assessment, which probably is not used to the extent that it might be, is the self-assessment instrument. Such an instrument enables students to rate their progress toward achievement of the objectives in a course, a unit or a daily lesson. The instrument consists of a listing of the performance objectives and a choice of rated responses from low to high achievement. This form of evaluation also can be used to show growth as a result of studying the unit by having students complete the form before and after the study.

Evaluation. The evaluation of student performance or of the science program represents the judgment made relative to the accomplishments of the student or the success of the program. Student assessment and the evaluation that follows are thought of as a means of arriving at a grade for the lesson, unit or course. Testing is an important part of the assessment process. However, one should not lose sight of the other interpretations which can be given to test results. If there is a significant difference between a student's score and the teacher's perception of her or his ability, time should be spent to diagnose the cause. If many students miss items which seem to have been well covered, then time should be spent to examine the science course or program, including such elements as teaching methodology, the suitability of the teaching materials, and the adequacy of facilities and school support. Assessment and evaluation should be an ongoing process that is one segment of the total learning experience. A listing of assessment and evaluation sources appears in the resource section at the end of this chapter.■

Assessing Student Progress Systemwide

Most school districts do not assess student progress in science toward their curricular objectives on a systemwide basis. At the elementary school level, a number of districts use commercially developed standardized tests – a portion of each test is devoted to science. Sometimes the objectives of the tests are well correlated with the objectives of the science program in a particular district; often they are not. Some school districts and states now are identifying a core of science objectives for the elementary grades (K-6) and devising a systemwide or statewide test to assess progress toward them. This procedure gives some assurance that appropriate topics are taught in all classes and in a sequential manner. To assess student performance and to evaluate program effectiveness, this approach is well worth the consideration of the science curriculum committee and the school district.■

Performance Assessment

The Connecticut State Department of Education, under a grant from the National Science Foundation, is developing assessment instruments that lean heavily upon the performance of students. The instruments, which differ from traditional multiple choice test formats, include the use of open-ended responses, the analysis of data and the synthesis of conclusions based upon these analyses, and the assessment of student performance in hands-on laboratory situations. The assessments are directed toward *Connecticut's Common Core of Learning* (1987). The purpose of this approach to assessment is to provide a better look at what the student is capable of doing and to move instruction away from plain rote methods and toward activity-oriented learning.■

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PROFESSIONAL DEVELOPMENT 11

"... I feel compelled to state, as emphatically as I can, my conviction that the primary intellectual qualification of a teacher is to know the subject being taught."
– Warren Weaver

Connecticut Mandate
Professional Development Guidelines
Federal Support
National Science Foundation
State Support Through ITL
Higher Education
Regional Educational Service Centers
Professional Associations
Learning Centers
Business and Industry
Local Staff Development
Regional Staff Development

8?

Science is a dynamic, self-correcting and constantly expanding enterprise. This means, of course, that teachers of science need to keep abreast of new developments, and science curriculum materials need to be continually updated. The knowledge explosion and the tremendous rate of change in many scientific fields means that teachers can fall behind and science curriculum materials can be seriously outmoded in a relatively short time unless there is a planned and ongoing program for staff development and curriculum revision.■

Connecticut Mandate

Recognition of this need to constantly update and expand the teacher's area(s) of expertise has resulted in new regulations (P.A. 88 - 273, signed into law May 6, 1988) which mandate that every teacher seeking renewal of the Professional Educator Certificate must successfully complete at least nine continuing education units (CEUs) during each successive five-year period of teaching. In addition, Connecticut General Statute 10-220a requires that every local and regional school district in Connecticut have a five-year plan for professional development. Thus, a carefully planned program of staff development is a high priority for every school system. In terms of the special needs of science teachers, there are three basic areas in which they may require assistance in remaining up-to-date:

- new developments in the natural sciences, particularly in the area(s) they teach;
- new science curriculum projects and teaching materials; and
- new and/or alternative methods of teaching.■

Professional Development Guidelines

The following guidelines for professional development represent a summary of "best practices" derived from a review of published studies dealing with effective in-service programs and projects:

- In-service education is most likely to be effective when teachers have participated in planning the program and when the program is responsive to their particular needs and interests.
- Single-session workshops can be very effective when the aim is to create awareness or to provide updating in a specific area. However, for most other developmental goals, an extended in-service program – with opportunities for teachers to practice and implement new knowledge, skills and attitudes in their own classrooms between in-service sessions – usually produces better results than "one-shot" or "quick-fix" efforts.
- Effective in-service programs include concrete learning experiences that place teachers in active roles such as developing curriculum materials, simulating new techniques and problem solving, rather than simply placing teachers in passive listening roles and expecting them to "store-up" knowledge.
- Well-coordinated programs "follow the teacher" back into the classroom by providing such support services as model lessons, supervised practice and peer coaching.
- When principals work side-by-side with their teachers during in-service sessions they not only demonstrate in a very unambiguous way the great importance placed on improving science education, but they also are better able to provide their teachers with informed and empathetic support.
- It is important not to underestimate the length of time that may be needed for significant change. Indeed, it may take one to several years for teachers to implement and become comfortable and skillful with new concepts and techniques they have acquired in in-service programs.■

Federal Support

Local school districts can obtain considerable support for professional development activities from entitlement grants funded by the federal government. In Connecticut, Title II of the Dwight D. Eisenhower Mathematics and Science Education Act funds are administered by the State Department of Education and the Department of Higher Education. Current Title II programs have fostered professional development for teachers of science from kindergarten through Grade 12 in areas ranging from elementary school science activities in physical science to microcomputer-based laboratories.

The following activities are representative of those allowed under Title II:

- in-service workshops sponsored by one or more school districts, by consortia or by regional educational service centers;
- academic year or summer in-service programs sponsored by colleges and universities;
- half-day or full-day workshops taught by local district staff, outside consultants or university faculty;
- the purchase of materials, supplies or a limited amount of equipment to be used in training, retraining or in-service training; and

- the meeting of transportation, tuition or other participant support costs related to in-service training or professional development activities.■

National Science Foundation

The National Science Foundation again has become quite active in supporting activities involving professional development for teachers and the creation of new curriculums. Connecticut has been fortunate in receiving a number of these grants. Topics such as robotics, energy, elementary school science and coastal biology have received greater attention in the schools as a result of this support.

Since technology now plays a greater role in the schools, the National Science Foundation has initiated a new category for grants to address the issues brought about by this development. Other categories involve cooperative efforts between business, industry and educational institutions in the development of new programs; an emphasis on urban programs; and the networking of information gathered by students and teachers to allow for greater communication and participation.■

State Support Through ITL

The Connecticut State Department of Education's Institute for Teaching and Learning (ITL) is another important avenue for local school districts seeking support for professional development activities. The stated purpose of the ITL is: "To offer professional development experiences to Connecticut teachers and educational leaders by providing training sessions which offer practical classroom application of current research about teaching." This program encourages successful, experienced teachers to share their knowledge and skills with other teachers, usually within the format of intensive, week-long summer institutes. In this way, the lead teachers (ITL directors) experience new challenges and satisfactions related to being a teacher of teachers, and the participating teachers engage in activities that update and extend their professional competencies.

The ITL program makes it possible for teachers to participate in a broad spectrum of institutes which are responsive to a variety of special needs and interests. Appropriate science programs may include, but are not limited to such topics as science process skills, inquiry techniques, laboratory procedures, new curriculum projects, science-technology-society interactions, problem solving and scientific literacy. The majority of institute programs are week-long sessions (20-40 hours) held during the summer, often with one or more follow-up meetings during the next school year.

The State Department of Education issues a call for proposals in the early fall of each year and the due date for applications usually is in mid-December. Local and regional school districts, the regional vocational technical school system, colleges and universities, regional educational service centers, teacher centers, other state agencies and other nonprofit agencies may submit proposals. However, individuals may submit proposals only through one of the above organizations. All proposals selected for funding are administered by one of the regional educational service centers.■

Higher Education

Connecticut is dotted with many institutions of higher learning, a number of which have long traditions of helping preservice and in-service teachers. State-supported institutions include the University of Connecticut and its branch campuses, The Connecticut State University (formerly the four state colleges), the 12 community colleges and the five technical colleges. The private colleges and universities in Connecticut provide another major resource. All of these institutions can help teachers in various ways, including formal courses, dissemination sessions and independent study opportunities. In addition, some of these institutions provide special programs for teachers. Current offerings include the following:

- **Central Connecticut State University.** Institute for Science Education. The institute offers advanced courses in biology, chemistry, earth science and physics.
- **Eastern Connecticut State University.** Institute for Marine Environmental Education. This institute is offered in cooperation with Project Oceanology (Avery Point, Groton). It includes a summer on-the-water program for K-12 teachers as well as a series of special field courses (marine expeditions).
- **Quinnipiac College.** Computers in Science and Mathematics. Middle school and secondary teachers are provided with a series of computer workshops in science and mathematics.
- **Sacred Heart University.** A variety of workshops for elementary and secondary school teachers. Sacred Heart University also maintains a library of Project Seraphim computer software, a project of the American Chemical Society. SMARTNET, a multidistrict project operated in cooperation with Scared Heart University, provides a broad spectrum of science in-service activities.
- **Northwestern Community College.** This

college hosts conferences for the northwestern region of the state. Its activities concentrate on elementary school science, mathematics and aspects of computer usage.

- **Wesleyan University.** Project to Increase Mastery in Mathematics and Science (PIMMS). PIMMS includes a variety of special institutes with funds and support from many sources in education, business, government and industry. Elementary and middle school teachers of science and mathematics study together in courses and seminars in preparation for service as (1) resource teachers in their own schools, (2) consultants on curricular matters to any school district requesting such service, and (3) leaders of workshops and other professional development programs for teachers.■

with the Council for Elementary Science International (CESI) to allow teachers to obtain dual memberships and the publications of both associations.

The Connecticut Science Supervisors Association (CSSA) is an active organization that addresses the concerns of science department heads. Attendance at its meetings, however, is open to all interested parties. The association holds meetings about four times a year.

Each subject matter discipline has an association (e.g., National Association of Biology Teachers, New England Association of Chemistry Teachers, American Association of Physics Teachers) dealing with concerns specific to that discipline. Teachers should be encouraged to join and become involved with these and the other more general science associations such as the National Science Teachers Association. In this way teachers will be better able to remain abreast of the many changes taking place in the field.■

Regional Educational Service Centers

Connecticut's regional educational service centers (RESCs) are responsive, flexible and available to local school districts. These centers are capable of bringing together a wide variety of human, natural and technological resources to meet specific needs at specific times in special (often local) situations. Teachers can turn to these centers for print and nonprint materials, literature searches, curriculum materials and a variety of in-service workshop sessions. (See Appendix K for addresses of the six centers in Connecticut.)■

Professional Associations

One of the best ways of obtaining information and staff development experiences about recent happenings in science education is through science teachers associations.

The National Science Teachers Association (NSTA) publishes a number of journals, newsletters, monographs and position statements which may be helpful.

The Connecticut Science Teachers Association (CSTA) publishes a newsletter which appears six to eight times a year and a journal which is published [illegible] or three times per year. CSTA also provides at least one [illegible] meeting and several regional meetings each year. These events bring together college and public [illegible] people who make presentations in their areas [illegible] [illegible]. Vendors of commercial science instructional materials often attend these meetings and [illegible] latest products. Thus, these meetings are [illegible] effective way for teachers to [illegible] their knowledge and skills. For [illegible] elementary school science. [illegible]

Learning Centers

Connecticut has a number of learning centers offering professional development opportunities in specialized areas of science. Among the most popular are the following:

- **Project Oceanology, Avery Point, Groton.** Project Oceanology serves a number of school districts in Connecticut by providing activities for teachers and students in topics concerned with the aquatic environment. The project has grown dramatically over the years and now provides programs for areas of Massachusetts and New York as well. Students and teachers can receive instruction in both the life and physical sciences as they relate to the marine world.
- **Talcott Mountain Science Center, Avon.** This center offers a variety of services and materials to teachers and their students. Two of its most recent innovative programs are: (1) "On the Shoulders of Giants" a seminar series in which distinguished scientists visit the center and interact with teachers and students, and (2) "Scistar" an interactive video program transmitted by satellite which offers in-service programs to teachers throughout the state and across the country.
- **Thames Science Center, New London.** A number of innovative programs currently available for [illegible] teachers. Some of these are [illegible] "Project [illegible]otACTS" [illegible] during which teachers build [illegible] and evaluate interactive [illegible] and [illegible] materials that can then be

integrated into their physical science curriculums; (2) "Project Science SKILLS" – a series of workshops for elementary and secondary teachers with hands-on activities, materials and research-oriented projects designed to increase student interest in the natural and technological resources of eastern Connecticut; and "Project Porifera" – a summer institute that integrates aquatic biology and computer science. Through a combination of field and laboratory activities, teachers learn to guide their students in an ongoing survey of chemical, biological and physical characteristics of streams, rivers and estuaries of Eastern Connecticut.■

Business and Industry

Over the years, many businesses and industries have supported projects and activities undertaken by students and teachers. Recently, perhaps due to the growing interest in the importance of science education as related to the needs of an increasingly technical society, more formal relationships have developed between business and industry and the schools.

SNET, in cooperation with the State Department of Education, administers a yearly program called the Celebration of Excellence to recognize excellent teachers. Among those who have received recognition are a number of teachers of science. In order to participate, teachers must apply and prepare a report of an activity that they believe to be worthy of recognition.

The Connecticut Business and Industry Association administers a Fellowship Program for Distinguished Teachers. This program places teachers in industrial or business positions for the summer months. Every effort is made to arrange for a position that will allow the teacher to use the skills and knowledge gained in the industrial setting back in the classroom. The program, in operation since 1984, has placed teachers in a number of well-known industries in the state.

Some businesses provide professional development activities on topics that are related to areas of their own expertise. For example, some chemical and pharmaceutical companies have arranged for workshops dealing with safety in the laboratory. Utilities have provided professional development activities in the area of energy, while some "high-technology" industries have provided experiences involving the development and use of the newer technologies.

The willingness of businesses and industries to assist in the improvement of science education should not be ignored. For the most part they are willing to assist and, in general, have been most cooperative in providing activities of a wide variety to students and teachers of science.■

Local Staff Development

There are a number of other important programs that can be operated at the local level to encourage and support personal and professional growth. Most of these initiatives are relatively inexpensive, and some may seem disarmingly simple, but they have considerable potential value for professional development, especially in terms of encouraging greater cooperation and teamwork among fellow teachers and better articulation and sharing between schools and school systems.

Self-study and self-improvement, for example, can be encouraged by providing teachers with easy access to audio and video recording equipment. This will enable teachers to record and preserve sample lessons for later study and analysis. In a similar way, teachers can be encouraged to team up with one or more colleagues and take turns visiting one another's classrooms. Teachers who cooperate in this way then are able to exchange valuable information and informal feedback about classroom interactions. In addition, such classroom visits by fellow staff members can be an important way for each teacher to observe and study other examples or models of teaching. Many teachers work alone and seldom, if ever, see colleagues in action in classroom settings. It is unfortunate that such an inexpensive and simple approach to staff development – informal classroom visits by fellow teachers – is not used by more school systems.

Many teachers never have received any formal training in how to study their own teaching behaviors. Most teachers spend years to acquire mastery of their subject matter but often have devoted little or no formal study to their actual performance – verbal and nonverbal behavior – in the classroom. Thus, there may be great potential gain for local districts to encourage teachers to engage in efforts to learn more about the art of teaching. In recent years, a number of methods have been devised that can be used by teachers to study and analyze their own teaching behaviors.

The *Design For Effective Instruction* material by Madeline Hunter, Flander's Interaction Analysis and Teacher Expectations and Student Achievement (TESA) and programs on learning styles are helpful systems that can be used by individual teachers or small teams to study and improve their teaching. By providing time and the appropriate study materials, local school systems can be very helpful and influential in this area of staff development.

In-service sessions can be another avenue to staff development. These usually take the form of mini courses or single-topic workshops dealing with new developments in science and science curriculum and are taught by a local supervisor or special resource teacher, e.g., PIMMS fellow, Operation Physics instructor or a person from a nearby college. Each school system should take care not to overlook other potentially valuable local re

sources for staff development and curriculum enrichment such as amateur and hobby organizations (e.g., astronomy club), health organizations (e.g., American Red Cross), local industries (e.g., American Cyanamid), government agencies (e.g., the United States Submarine Base in New London) and local historical societies.

Another fairly simple and direct way of encouraging and supporting staff development is to provide easy access to resource materials. Professional and scientific books and journals can be of assistance to teachers interested in acquiring innovative and up-to-date materials and techniques. There are many helpful resource materials and new ones are published every year. Each school system should allocate funds on an annual basis for the acquisition of new books and for journal and magazine subscriptions. A listing of a sampling of the books and journals that can be housed in a departmental or school library is found at the end of this chapter.■

Regional Staff Development

Regional resources for staff development usually are more varied and extensive than those available locally, but also require more cooperation, coordination and planning.

A basic first step may be to encourage teachers to visit their counterparts in nearby towns. Released time granted for such visits – two or three times a year – should improve interschool communication and sharing and make it unnecessary for each school to "reinvent the wheel." There are many educational resources within driving distance of virtually all school systems. Personnel from school systems should look into these resources when considering possibilities for credit and noncredit courses to train, retrain or update their teachers. The staff at a zoo, for example, might agree to offer a mini-course designed to give teachers information about the natural history of vertebrates, the behavior of animals in captivity, and the care and treatment of small native animals. Likely resources that might assist school systems by offering workshops for teachers include the following:

Aquariums

- setting up aquarium tanks
- underwater photography
- marine science

Agricultural Experiment Station

- plant pollination
- incubating baby chicks
- hydroponic procedures

4-H Extension Centers

- tree identification
- raising small farm animals
- nutrition, food preparation and preservation

Historical Societies

- Connecticut inventors
- great moments in Connecticut science and technology

Nature Centers

- ecology and natural history
- sidewalk (urban) ecology

Science Museums

- evolution of dinosaurs
- endangered species
- fossil man

Planetariums

- celestial navigation
- new knowledge of the solar system
- stellar evolution

Zoos

- humane treatment of small native animals and pets
- animal communication
- learning and conditioning techniques

A number of state agencies also might be able to help with science staff development by supplying materials, workshops or opportunities for summer internships. School systems should not overlook potential assistance from such state agencies as the Connecticut Geological and Natural History Survey, Department of Environmental Protection, fish hatcheries and tree farms.■

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Appendix A
Statewide Educational Goals For Students – 1991-1995

Goal One: Motivation to Learn

Students must be motivated to learn and to respond to the high expectations of their parents, teachers and school administrators and to their own inherent need to grow and develop. Connecticut public school students will:

- develop self-understanding and a positive self-concept;
- understand and strive to fulfill their own personal aspirations;
- develop positive feelings of self-worth which contribute to self-reliance, responsible behavior, personal growth, health and safety;
- demonstrate strong motivation and persistence to learn; and
- exhibit an inquisitive attitude, open-mindedness and curiosity.

Goal Two: Mastery of the Basic Skills

Proficiency in the basic skills is essential for acquiring knowledge and for success in our society. Connecticut public school students will:

- learn to communicate effectively in speech and writing;
- listen, view and read with understanding;
- acquire knowledge of and ability in mathematics;
- demonstrate skills necessary to locate and effectively use a variety of sources of information, including print materials, media, computers and other technology;
- demonstrate decision-making, reasoning and problem-solving skills alone and in groups; and
- demonstrate good study skills and skills necessary for lifelong learning.

Goal Three: Acquisition of Knowledge

Acquiring knowledge leads to fuller realization of individual potential and contributes to responsible citizenship. Connecticut public school students will:

- acquire the knowledge of science and technology, mathematics, history, social sciences, the creative and performing arts, literature and languages;
- acquire the knowledge necessary to use computers and other technologies for learning and problem solving;
- acquire an understanding and appreciation of the values and the intellectual and artistic achievements of their culture and other cultures; and
- take full advantage of opportunities to explore, develop and express their own uniqueness and creativity.

Goal Four: Competence in Life Skills

As adults, students will be challenged to function successfully in multiple roles – as a citizen, family member, parent, worker and consumer. Connecticut public school students will:

- demonstrate an ability to make informed career choices;
- understand the responsibilities of family membership and parenthood;
- demonstrate the ability to undertake the responsibilities of citizenship in their communities, in the state, in the nation and the world;
- understand human growth and development, the functions of the body, human sexuality and the lifelong value of physical fitness;
- understand and apply the basic elements of proper nutrition, avoidance of substance abuse, prevention and treatment of illness and management of stress;
- understand and develop personal goals and aspirations; and
- upon completion of a secondary-level program, demonstrate the skills, knowledge and competence required for success in meaningful employment, and be qualified to enter postsecondary education.

Goal Five: Understanding Society's Values

As responsible citizens, students will enrich their family, community and culture and create equal opportunity for all persons to participate in and derive the benefits of their society. Connecticut public school students will:

- respect and appreciate diversity;
- understand the inherent strengths in a pluralistic society;
- recognize the necessity for moral and ethical conduct in society;
- understand and respond to the vital need for order under law;
- acquire the knowledge to live in harmony with the environment, and actively practice conservation of natural resources;
- respect the humanity they share with other people and live and work in harmony with others;
- acquire and apply an understanding and appreciation of the values and achievements of their own culture and other cultures; and
- show understanding of international issues which affect life on our planet and demonstrate skills needed to participate in a global society.

From *Challenge For Excellence: Connecticut's Comprehensive Plan for Elementary, Secondary, Vocational, Career and Adult Education*. Connecticut State Board of Education, April 1990.

APPENDIX B

LEGISLATION

This *Guide To Curriculum Development in Science* is consistent with the provisions of Section 10-4 and 10-16b of the *Connecticut General Statutes.*

Section 10-4. Duties of Board. (a)... shall prepare such courses of study and publish such curriculum guides... as it determines are necessary to assist school districts to carry out the duties prescribed by law...

Section 10-16b. Prescribed courses of study. (a) In the public schools the program of instruction offered shall include at least the following subject matter, as taught by legally qualified teachers: the arts; career education; consumer education; health and safety, including, but not limited to, human growth and development, nutrition, first aid, disease prevention, community and consumer health, physical, mental and emotional health, including youth suicide prevention, substance abuse prevention and safety and accident prevention; language arts, including reading, writing, grammar, speaking and spelling; mathematics; physical education; science; social studies, including, but not limited to, citizenship, economics, geography, government and history; and in addition, on at least the secondary level, one or more foreign languages and vocational education.

(b) Each local and regional board of education shall on September 1, 1982, and annually thereafter at such time and in such manner as the commissioner of education shall request, attest to the state board of education that such local or regional board of education offers at least the program of instruction required pursuant to this section, and that such program of instruction is planned, ongoing and systematic.

(c) The state board of education shall make available curriculum materials and such other materials as may assist local and regional boards of education in developing instructional programs pursuant to this section.

APPENDIX C
THREE-COLUMN FORMAT
EXAMPLE FROM "BIOLOGY"

The following is used with the permission of The State Education Department, Albany, NY.

Unit 2 – Maintenance of Animals

The following statements provide a frame of reference for Unit 2:

- The animal examples used are treated horizontally with each life function being treated once for each representative organism.
- Evolutionary trends evident in comparing each representative are stressed.
- Emphasis is placed on the relationship between structure and function.
- Chemical concepts are treated descriptively and are introduced at points appropriate to the understanding of biological principles.

Topics	Understandings and Fundamental Concepts	Supplementary Information
	The maintenance of animal life is dependent on universal requirements: • obtaining and distributing essential organic and inorganic compounds • removal of metabolic waste products • regulation of process	
I. Nutrition		
A. Process	Nutrition includes those activities of animals by which they obtain and utilize various substances (known as nutrients or foods) for metabolic activity. Foods or nutrients are substances that serve as: • energy sources for various life activities of cells • constituents in the building or repair of cell structures • regulators of metabolic processes	While nutrition may be extended to include all activities and destinies of consumed materials, only intake and processing of nutrients are treated in this section. The distribution and specific roles of physiological compounds are described in later sections.
	Animals lack the ability to synthesize nutrients from inorganic raw materials and must consume preformed organic compounds. This mode of nutrition is known as heterotrophic nutrition. Usually, other organisms (plants and/or animals) are consumed by animals and serve as a source of preformed nutrients. Food organisms may contain unnecessary or unavailable compounds as well as those with nutritional value.	

THREE-COLUMN FORMAT EXAMPLE FROM "BIOLOGY"

Topics	Understandings and Fundamental Concepts	Supplementary Information
1. Ingestion	Ingestion describes those activities of animals by which they take in materials (compounds and/or organisms) which serve as a basis for nutrition.	
2. Digestion	Digestion involves the reduction of large or insoluble food materials to small, soluble molecules which may be distributed throughout an animal and used for various physiological activities. Digestion may occur within cells (intracellular) or outside of cells (extracellular).	
a. Mechancial aspects	Many animals exhibit adaptations which permit the breakdown of food materials to small particles through purely physical means such as grinding, cutting, and tearing.	
b. Chemical aspects	Mechanical digestion reduces food materials to particles which, by molecular standards, are still exceedingly large. Further reduction to soluble form is accomplished through the action of enzymes.	
(1) Enzyme action	Enzymes are proteins which act as catalysts and affect many physiological reactions, including digestion. Digestive enzymes are hydrolytic. They promote the breakdown of large molecules to small unit molecules with the addition of water. The name of an enzyme is usually formed by adding the ending -ase to a stem which is taken from the substrate (compound, or class of compound) upon which the enzyme acts. Some examples of digestive enzymes and thier substrates include: **Enzyme** — **Substrate** maltase — maltose lipase — lipids protease — protein Enzymes are specific in their action. They will usually only catalyze reactions involving a single substrate compound or a group of closely-related compounds. Temperature and hydrogen-ion concentration (pH) are two of the factors which determine the rate of enzyme action.	Teachers who do not select the BC extension of Unit 1 may wish to examine section C of the BC extension for additional treatment of enzymes.

Topics	Understandings and Fundamental Concepts	Supplementary Information
(2) Outcome	As a result of the action of enzymes in chemical digestion, complex organic molecules are hydrolyzed to smaller, soluble molecules. • carbohydrates (sugars, starches, etc.) are converted to simple sugars such as glucose • proteins are converted to amino acids • lipids (fats, oils, etc.) are converted to fatty acids and glycerol	
B. Adaptations	Nutritional patterns among animals vary in accordance with the adaptations which have evolved to permit the ingestion and digestion of food materials.	Although protozoa are classified by many biologists as protists (see Unit VI, Section C: A Modern Classification System), they are compared with animals in this section because they exhibit animal-like characteristics and are thought to be decendants of evolutionary precursors to multicellular animals.
1. Protozoa	Protozoa ingest food organisms by taking them in through fixed openings (as in paramecium) or engulfing them (as in amoeba). Protozoa have no digestive tract. Ingested food materials accumulate in food vacuoles where digestion occurs. Digestion is intracellular.	

From *General Biology Syllabus*
The State Education Department, Albany, NY
Used with permission

Appendix D
Four-Column Format Example From "General Chemistry"

The following is used with the permission of The State Education Department, Albany, NY.

Area 6 – Environmental Pollution

Topical Outline	Understandings and Concepts	Laboratory Experiences	Supplementary Information
1. Introduction	A pollutant is a substance found in the environment which normally is lacking, or, if naturally occurring, is found in greater than normal concentrations.		
	Pollutants may be natural or man-made.		Natural pollutants include pollen, dust, silt, and microbes Man-made pollutants include sewage, pesticides, industrial wastes, and automotive emissions.
	Contamination of our environment has increased to a point that it is a serious threat to the health and economic welfare of society.		The rate at which man adds pollutants to the environment is so great that some authorities estimate that the total amount of pollution in the world doubles every 10 years.
	In the past, man has depended on dilution and natural purification processes to control pollution.		Man can no longer depend upon natural processes for pollution control.

Topical Outline	Understandings and Concepts	Laboratory Experiences	Supplementary Information
	Factors which contribute to the increasing contamination of the environment are the population explosion, the growth of large urban centers close to each other, and the desire for an ever higher standard of living.		
	The first important requirement of a pollution control program is an aroused community of informed citizens and officials.		Discuss the role of the individual and of local, state, and federal governments in controlling pollution. Legislators, lawyers, public health officials, and sanitary engineers are good resource people for class visitations, either in person or via tape.
	Pollutants may be found in water, in air, and/or on land. A particular activity of man may cause pollution in all three areas.		People in their daily living activities add pollutants to the environment when they drive automobiles, heat their homes, discharge sewage, dispose of refuse, etc.
II. Water			
A. Water supply	Man obtains most of his water from surface water and ground water.		Surface water includes lakes, rivers, streams, and reservoirs. Ground water is water naturally found beneath the surface of the earth.

Topical Outline	Understandings and Concepts	Laboratory Experiences	Supplementary Information
	The total amount of water on earth remains relatively constant. Water is continually circulating through a cycle of precipitation, runoff, infiltration, storage, evaporation, and reprecipitation called the water cycle.	A terrarium can be used to illustrate the natural water cycle. If a terrarium is unavailable, a sealed plastic bag containing a little water can be used to show the processes of evaporation and condensation.	The demand for fresh water has been increasing. Some surveys indicate a shortage of fresh water in the future. The population of the United States increased two and one-half times from 1900 to 1960, but the use of water per day increased four times for the general population, seven times for agriculture, and 11 times for industry.
	The water from a major river can be used many times as it flows from the source of the river to its mouth. The only practical solution to a shortage of fresh water is more reuse of the same water.		
	When water from precipitation and "returned" ground water are not added to the water table at the same rate that they are removed, the depth of water in the table decreases and a water shortage may occur.		The lowering of the water table in some parts of the country is a matter of great concern.
B. Naturally occurring substances in the water supply			
1. Rainwater	Naturally occurring substances found in rainwater include fine particles of salt, dust, and smoke which served as condensation nuclei. The principal gases from the air dissolved in rainwater are oxygen, nitrogen, and carbon dioxide.		Traces of ozone, nitrogen oxides, argon, sulfur dioxide, ammonia, and other gases may be present in rainwater.

Topical Outline	Understandings and Concepts	Laboratory Experiences	Supplementary Information
	Most rainwater is weakly acidic because of the carbon dioxide dissolved in it.	Test the pH of rainwater.	The pH value of rainwater ranges from 5.5 to 6.0.
2. Ground water	When weakly acidic rainwater falls upon the earth, more carbon dioxide is taken up as the water infiltrates the soil, flows in streams, and/or is stored. Substances that dissolve in weak acids are leached by the ground water. This reduces the acidity and increases the concentration of minerals in the water.	Test the pH of ground water.	Ground water containing weak alkaline materials may have a pH range of 8.0 to 8.5.
	Water containing ions of calcium, magnesium, and/or iron is called hard water.	Compare the number of drops of "standard" soap solution needed to produce suds in samples of water from different sources.	The number of drops of standard soap solution necessary to produce suds is a rough measure of the degree of hardness in water.
	Hard water renders soap ineffective as a cleaning agent.	Soap solutions can be "standardized" by comparing the number of drops needed to produce suds in distilled water.	Students may encounter the unit parts per million (p.p.m.). The unit is used to express small concentrations of substances in water without using fractions.
		Evaporate water from different sources and compare the amount of residue. Ignite the residues. Inorganic residues will not char. Organic residues will char.	1.0 p.p.m. = 1 mg./liter 1 liter water = 1,000,000 mg. water 1 p.p.m. = 1 mg./1,000,000 mg. water

Topical Outline	Understandings and Concepts	Laboratory Experiences	Supplementary Information
		Demonstrate that the ability to conduct electricity is a way of measuring the concentration of dissolved minerals.	
C. Water pollutants			
1. Sewage	Sewage is water carrying human, animal, or organic wastes from homes, industrial establishments, or other places.		Fresh sewage is a turbid liquid containing organic and inorganic "solids" which may be dissolved, suspended, or floating.
	Sewage contains human and animal body discharges, household wastes, street washings, ground water, infiltration, and industrial wastes.	Activity 6.01 may be used to detect oil in street washings.	Organic solids include animal and plant waste products, dead animal matter, plant tissue, and synthetic organic materials such as soaps, detergents, frothing agents, and grease.
			Inorganic matter in sewage includes sand, grit, gravel, silt, and mineral salts.
	Bacterial action causes the decomposition of organic matter.		The bacteria may use organic matter for food and decompose it into simpler substances.

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The State Education Department, Albany, NY
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Appendix E
Domains, Skills And Concepts For Connecticut Secondary School Science Subjects

Biology

DOMAINS

A. GENERAL SKILLS AND CONCEPTS
B. CHEMISTRY OF LIFE
C. CELL BIOLOGY
D. ENERGETICS
E. DIVERSITY AND RELATIONSHIPS AMONG CELLS AND ORGANISMS
F. ECOLOGY
G. GENETICS AND BIOETHICAL ISSUES
H. HUMAN BIOLOGY

A. GENERAL SKILLS AND CONCEPTS

1. Computation, scientific	Demonstrate knowledge of measurement and of computational skills, such as significant figures, scientific notation and scientific measurement
2. Data tabulation, graphs	Tabulate data, construct and interpret graphs and charts
3. Scientific technology	Describe the role of technology and relate content on technological advances
4. Terminology	Identify appropriate laboratory and field terminology
5. Laboratory skills and processes	Demonstrate proper use and care of laboratory equipment
6. Laboratory and field safety	Use basic laboratory and field safety techniques
7. Methods of science	Demonstrate and use basic scientific methods, including experimental design, reasoning, analysis and reporting techniques
8. History of biology	Identify events and persons instrumental in the historical development of biology (e.g., Pasteur, Darwin, Mendel, Crick)

B. CHEMISTRY OF LIFE

9. Basic chemistry	Understand the role and action of inorganic compounds found in living cells (e.g., bonding, ions)
10. Biochemistry	Understand the basic principles of biochemistry (e.g., proteins and macromolecules, hydrolysis, synthesis)

C. CELL BIOLOGY

11. Cell theory	Understand the historical evidence and developments that support the cell theory
12. Structure and function of cells	Describe the organelles present in typical plant and animal cells and their functions
13. Intra- and extracellular	Understand the mechanisms of intra- and extracellular transportation (e.g, diffusion, osmosis, active transport)
14. Cellular reproduction	Understand processes of cellular reproduction and differentiation, including mitosis and meiosis, asexual and sexual reproduction, and gastrula formation

D. ENERGETICS

15. Respiration	Understand the basic concepts of aerobic and anaerobic respiration (e.g., fermentation, ATP formation)
16. Photosynthesis	Understand the basic concepts of photosynthesis (e.g., light phase, dark phase)
17. Chemosynthesis	Understand the basic concepts of chemosynthesis

E. DIVERSITY AND RELATIONSHIPS AMONG CELLS AND ORGANISMS

18. Theories of evolution	Understand the basic concepts and supporting evidence of the evolutionary theories
19. Taxonomy: the five kingdoms	Understand the distinguishing characteristics and use of the five-kingdom system of classification
20. Morphology and physiology of vascular plants	Understand the structure and function of the leaf, root, stem and flower of vascular plants, including plant growth and responses
21. Morphology and physiology of animals	Identify characteristics of groups of organisms in the animal kingdom and understand the structure, function, behavior and economic importance of specific animals

F. ECOLOGY

22. Ecological principles	Understand the carbon, oxygen and nitrogen cycles, their effects on living organisms, and the interrelationships between abiotic and biotic factors in the environment
23. Communities, biomes, nutritional relationships	Identify the characteristics of communities and biomes, and the nutritional relationships that exist in them (e.g., producers, consumers, decomposers)

24. Population dynamics	Understand the role of population dynamics in ecology, including the interrelationships of living organisms, and the transfer and flow of food and energy (e.g., food web)
25. Ecological Concerns	Understand the role of human beings as interactive agents in conservation, utilization of energy, and pollution

G. GENETIC AND BIOETHICAL ISSUES

26. Patterns of heredity	Understand the principles of Mendelian genetics, including major concepts of chromosome theory
27. Cytogenetics	Understand the chemical basis of genetics, including DNA/RNA structure and its relation to genes, DNA replication and protein synthesis
28. Human genetics	Apply knowledge of principles of human genetics, including the inheritance of human traits and genetic abnormalities in contemporary life
29. Contemporary, societal, technological and ethical issues in biology	Analyze ethical issues arising from the impact of technological advances in biology on contemporary society (e.g., genetic testing and genetic engineering, in vitro fertilization)

H. HUMAN BIOLOGY

30. Anatomy and physiology of the human body	Understand the structure and function of human body systems, including support, digestive, circulatory, respiratory, excretory, nervous, endocrine and reproductive
31. Dysfunction and disease	Demonstrate knowledge of dysfunctions, diseases and types of immunity of the human body, including viruses and bacteria as disease-producing agents
32. Health issues	Demonstrate knowledge of the personal and societal issues related to good emotional and physical health (e.g., nutrition, substance use and misuse)

Chemistry

DOMAINS

A. GENERAL SKILLS AND CONCEPTS
B. FUNDAMENTAL CHEMICAL CONCEPTS
C. PHYSICAL CONCEPTS
D. ATOMIC AND MOLECULAR CONCEPTS
E. SOLUTION CONCEPTS

A. GENERAL SKILLS AND CONCEPTS

1. Observation	Demonstrate observational skills and distinguish between observation and interpretation
2. Scientific computation	Demonstrate knowledge of computational skills, such as use of significant figures and scientific notation, and unit analysis
3. Scientific measurement and instrumentation	Demonstrate knowledge of the function of scientific instruments (e.g., balances, pH meters, spectrophotometers)
4. Data tabulation, graphs and charts	Tabulate data and construct and interpret graphs and charts
5. Instructional technology	Understand the use of technologies (e.g., microcomputers, videocassettes, videodisks) in chemistry instruction
6. Terminology and techniques	Identify appropriate laboratory terminology as well as qualitative and quantitative techniques
7. Laboratory safety	Understand basic laboratory safety procedures, including proper storage and disposal of chemicals
8. Methods of science	Apply basic scientific procedures, such as experimentation, formulation of hypotheses, data interpretation and communication of results
9. History of chemistry	Identify events and persons instrumental in the historical development of chemistry (e.g., development of periodic table, atomic theory, Niels Bohr)
10. Application of concepts to societal issues	Apply chemistry concepts to issues in contemporary society (e.g., acid rain, nuclear power)

B. FUNDAMENTAL CHEMICAL CONCEPTS

11. Relationship between matter and energy	Apply the laws of conservation of matter and energy and transformation of matter and energy

12. Classification of matter	Understand the classification of matter and the physical and chemical properties of matter
13. Chemical notation: nomenclature, symbols, formulas and equations	Use and interpret proper nomenclature, symbols and formulas for elements and compounds, including notation used in the periodic table to write balanced chemical equations
14. Stoichiometry: the mole concept	Apply knowledge of the mole concept to solve problems involving the number of atoms, molecules, ions or moles, the empirical and molecular formulas, and the quantities of reactants and products in balanced chemical equations
15. Periodic table: organization and trends	Predict the physical and chemical properties of elements and the relationship among elements based on their locations in the periodic table

C. PHYSICAL CONCEPTS

16. Kinetic molecular theory	Apply the kinetic molecular theory to all states of matter
17. Gas laws	Understand the gaseous state of matter, including quantitative use of the gas laws to determine volume, temperature, pressure, mass, moles and density
18. Solids, liquids and gases	Identify the properties, structures and relationships of solids, liquids and gases, including vapor pressure and phase change
19. Mixtures	Identify the special characteristics of solutions, suspensions and colloids
20. Thermochemistry	Apply the principles of thermodynamics, including the concepts of enthalpy, entropy and free energy to the study of chemistry
21. Reaction rates	Understand the law of mass action and the effects of concentration, surface area, temperature, pressure and catalysts on reaction rates and reaction-energy diagrams
22. Oxidation and reduction	Understand oxidation and reduction, including oxidation number, electron transfer, methods of balancing equations and practical applications of oxidation-reduction reactions

D. ATOMIC AND MOLECULAR CONCEPT

23. Atomic structure	Analyze the structure of atoms according to the quantum theory
24. Electron configuration and behavior	Identify the electron configurations of various elements and the characteristics of electron behavior in atoms
25. Bonding	Understand the formation of chemical bonds and identify the characteristics of various types of bonds

26. Structure and properties of compounds	Relate bonding to observed properties of compounds
27. Organic chemistry	Understand the bonding, structure, properties, uses and typical reactions of common organic compounds
28. Nuclear chemistry	Apply the principles of radioactivity and nuclear reactions to the generation of energy and nuclear medicine
29. Polymers	Understand the formation, structure, properties and uses of common, natural and commercial macromolecular substances

E. SOLUTIONS

30. Solution concentration	Understand the various quantitative methods of determining and applying concentrations of solutions (e.g., molarity, molality, normality, percent solutions), including colligative properties
31. Arrhenius' Theory of Ionization	Understand the chemistry of electrolytes and the theory of ionization
32. Acids, bases and salts	Understand the theories, properties and characteristics of acids, bases and salts, including pH, K_a, K_b, K_{sp}
33. Equilibrium	Understand the quantitative and qualitative concepts of chemical equilibrium, including K_{eq} and LeChatelier's Principle
34. Electrochemistry	Analyze the structure, chemical reaction, charge movement, current flow and theoretical voltage of electrochemical and electrolytic cells and complete quantitative calculations involving the cells
35. Qualitative analysis	Demonstrate knowledge of wet chemical schemes for identifying anions and cation

Earth Science

DOMAINS

A. GENERAL SKILLS AND CONCEPTS
B. ASTRONOMY
C. GEOLOGY
D. METEOROLOGY
E. OCEANOLOGY

A. GENERAL SKILLS AND CONCEPTS

1. Nature of science	Apply the self-correcting characteristics of science, including experimental design, data collection, reasoning, analysis, predictability, verification and reporting techniques
2. Computation, exponential notation and scientific measurement	Demonstrate knowledge of computational skills, exponential notation and scientific measurement
3. Data tabulation, graphs and charts	Tabulate data and construct and interpret graphs and charts
4. Data and map interpretation	Interpret data presented in the form of celestial, topographic, weather/meteorological and geological maps
5. Laboratory and field safety	Understand basic laboratory and field safety procedures
6. Scientific technology	Understand the use of technology in earth science instruction and relate content to technological and practical application

B. ASTRONOMY

7. The origin of the universe	Understand the theory of the origin of the universe, including analysis of the evidence supporting the "Big Bang Theory"
8. Stars	Understand the types, composition and life cycles of stars
9. Solar system (star systems)	Identify the components and features of the solar system (e.g., planets, moons, asteroids), their characteristic patterns and the theory of the formation of the system
10. The Earth-moon system	Analyze characteristics of the Earth-moon system, including orbital characteristics, tides, eclipses, time and rotation
11. Historical astronomy	Identify individuals instrumental in the historical development of astronomy (e.g., Aristotle, Ptolemy, Copernicus, Galileo, Kepler, Newton, Hubble) and their contributions
12. Space exploration	Understand key projects of space exploration, Earth resource technology, coal mine scanning via satellite and their importance to life on Earth

13. Instrumentation and technology	Identify instruments and technology used in astronomy (e.g., telescopes, spectroscopes, remote sensing, rockets, satellites)

C. GEOLOGY

14. Minerals	Identify the composition/groups of minerals, their physical characteristics (e.g., hardness, cleavage) and their use
15. Rocks	Identify types and characteristics of rocks and interpret their origins
16. Plate tectonics	Understand the evidence in support of the paradigm of plate tectonics and the mechanism by which it is accomplished
17. Earth dynamics	Identify components of Earth's crustal dynamics, including mountain building, volcanic activity, folding and faulting of rocks, and components of Earth's interior dynamics, including structure, conduction and convection, and evidence of seismic activity
18. Weathering and erosion	Analyze chemical and mechanical weathering and the erosional processes involving water, wind and glaciers
19. Historical geology	Identify events instrumental in the historical development of geology (e.g., principles of uniformitarianism, catastrophism), the concepts of relative and absolute time and radioactive dating, and interpretive geology
20. Environmental concerns	Identify environmental concerns in geology (e.g., pollution, conservation, resource exploration and management)

D. METEOROLOGY

21. Distribution of energy	Analyze the flow of energy using conduction, convection, radiation and evaporation
22. Composition and dimensions	Understand the composition and dimensions of the atmosphere, including structure, composition and temperature profile
23. Weather parameters	Analyze weather parameters (e.g., temperature, pressure, humidity, cloud cover, winds)
24. Instrumentation	Interpret data from the instruments used to monitor weather parameters and changes and identify the use of these instruments
25. Weather systems	Understand the formation of weather systems (e.g., fronts, highs, lows)
26. Storms and precipitation	Understand the formation of storms and precipitation (e.g., thunderstorms, hurricanes, tornadoes)
27. Map analysis and forecasting	Understand the location of systems on a weather map and forecast their passage across the United States

28. Climate and climate modification	Identify characteristics of climate and the effect of various factors (e.g., pollution, volcanism or climate modification)
29. Weather and modification	Understand scientific attempts at weather control (e.g., cloud seeding)

E. OCEANOLOGY

30. Physical	Understand physical aspects of oceanology, including waves, tides, currents and physical properties of the sea
31. Chemical	Understand chemical aspects of oceanology, including chemical properties of water (e.g., composition, solubility, salinity)
32. Geologic	Understand geological aspects of oceanology, including sea floor spreading, topography and sedimentation
33. Biologic	Understand biological aspects of oceanology, including flora and fauna, nutrient cycles and ecosystems
34. Engineering and technology	Identify instruments used for oceanographic research and environmental concerns

Physics

DOMAINS

A. GENERAL SKILLS AND CONCEPTS
B. MECHANICS
C. KINETIC-MOLECULAR THEORY
D. WAVES AND OPTICS
E. ELECTRICITY AND MAGNETISM
F. 20TH CENTURY PHYSICS

A. GENERAL SKILLS AND CONCEPTS

1. Computation, scientific measurement, units	Demonstrate knowledge of metric system and trigonometric relationships, scientific notation, exponentiation and consistent use of units in calculations
2. Data tabulation, graphs and charts	Prepare tables, charts and graphs and read and interpret data presented in these forms
3. Graph analysis	Analyze and deduce relationships among data presented in graphs
4. Scientific technology	Understand various types of instruments used in the physics laboratory (e.g., meters, computers, scopes, oscilloscopes, diffraction devices)
5. Terminology	Define the terminology specific to a course in high school physics
6. Laboratory and field safety	Understand safety procedures related to the teaching of physics
7. Methods of science	Understand the methods and processes of scientific investigation
8. History of physics	Identify major events and persons instrumental in the historical development of physics (e.g., Kepler, Copernicus, Newton, Galileo, Einstein)

B. MECHANICS

9. Kinematics	Understand the concepts of distance, displacement, speed, velocity and acceleration and solve problems involving these concepts
10. Vector addition and subtraction	Understand and apply vector addition and subtraction to solve problems
11. Newton's Laws of Motion	Understand Newton's three Laws of Motion and their uses in solving problems with and without friction
12. Momentum and conservation	Understand momentum, impulse and elastic and inelastic collisions and solve problems involving these concepts

13. Circular and simple harmonic motion	Understand and apply the concepts of circular motion (e.g., centripetal force, angular velocity, angular acceleration, angular momentum) and recognize characteristics of simple harmonic motion (e.g., frequency, period, amplitude)
14. Newton's Law of Universal Gravitation	Understand Newton's Law of Universal Gravitation and solve problems involving changes in mass and distance
15. Energy, work and power	Understand the interplay among work, potential energy, kinetic energy and total energy, and differentiate between power and energy
16. Conservation of energy	Understand the concept of energy conservation and solve problems for mechanical systems

C. KINETIC-MOLECULAR THEORY

17. Kinetic theory	Understand the kinetic theory of motion, including its uses and limitations (e.g., contraction, expansion, gas laws, surface tension)
18. Laws of thermodynamics	Understand the basic principles of energy conservation and entropy
19. Temperature and heat	Understand the difference between temperature and heat
20. Heat transfer	Understand the mechanisms involved in conduction, convection and radiation
21. Change of state	Analyze change of state using kinetic-molecular theory, including the interpretation of graphs of the changes of state for various substances
22. Heat of fusion, vaporization and specific heat	Solve problems involving heat of fusion, vaporization and the calculation of specific heats of various substances

D. WAVES AND OPTICS

23. Characteristics of longitudinal and transverse wave motion	Understand how waves transfer energy and explain the difference between longitudinal and transverse wave motion
24. Characteristics of waves	Demonstrate knowledge of wave length, frequency and amplitude and solve problems involving these concepts
25. Electromagnetic spectrum	Identify different types of electromagnetic radiation (e.g., light, radio, microwave, X-rays) and analyze their similarities and differences
26. Wave and particle properties of light	Explain the wave and particle theories of light and the types of experiments for which they are best suited

27. Reflection and refraction	Understand reflection and refraction and use these concepts to solve problems (e.g., Snell's Law, geometric optics involving mirrors and lenses, total internal reflection)
28. Diffraction and interference	Understand constructive and destructive interference and use these concepts to explain diffraction

E. ELECTRICITY AND MAGNETISM

29. Static electricity	Understand the two kinds of electrostatic charge, and how they are produced, detected and moved
30. Electric fields	Understand properties of an electric field (e.g., field intensity, field direction)
31. Coulomb's Law	Understand Coulomb's Law and solve problems involving forces between charges
32. Current electricity	Understand direct current, and sources of potential and current resistance
33. Ohm's Law	Understand Ohm's Law and solve problems involving resistance, current, potential and power
34. Series and parallel circuits	Apply Ohm's Law to series and parallel circuits, and solve problems involving resistance, current, voltage and power for series, parallel and combined circuits
35. Magnetism	Understand the domain theory of magnetism, magnetic poles and magnetic force
36. Magnetic fields and forces	Understand magnetic fields, flux, flux density and permeability
37. Electromagnetism	Understand magnetic fields associated with charges in motion, including left- and right-hand rules, electromagnetic devices (e.g., meters, motors, transformers, alternating current, circuits and electronic devices)

F. 20TH CENTURY PHYSICS

38. Principles of quantum theory	Understand the theories that describe wave-particle duality, the energy of photons and the uncertainty principle
39. Photoelectric effect	Explain the photoelectric effect, work function and energy of ejected electrons, and the relationship of the photoelectric effect to quantum theory
40. Atomic structure	Understand various models of the structure of the atom, including Rutherford, Bohr and more modern models, and explain how each was developed
41. Radioactivity	Identify types of radioactive emissions (i.e., alpha, beta, gamma) and describe the processes of radioactive decay, fission and fusion

42. High-energy physics	Describe various particle accelerators (e.g., cyclotron, synchrotron, linear accelerator, colliding beams) and understand general categories of subnuclear particles (i.e., leptons, mesons, baryons, quarks)
43. Theory of relativity	Understand basic principles of the special theory of relativity, and the relations of mass and velocity, time and velocity, length and velocity, and mass and energy
44. Modern astrophysics and cosmology	Recognize the connections linking the "Big Bang Theory," stellar evolution and high-energy physics

General Science

DOMAINS

A. GENERAL SKILLS AND CONCEPTS
B. PHYSICAL SCIENCE
C. EARTH SCIENCE
D. LIFE SCIENCE

A. GENERAL SKILLS AND CONCEPTS

1. Mathematical calculation	Demonstrate knowledge of appropriate calculation skills (e.g., percent, average, decimals)
2. Measurement units	Demonstrate knowledge of measurement units (e.g., metric, linear, mass, volume)
3. Measurement equipment	Select and use appropriate measurement equipment (e.g., microscope, triple balance beam, meter stick, graduated cylinder, thermometer)
4. Tables, graphs and maps	Record and display data correctly in tables, graphs and maps, and interpret data presented in these forms
5. Lab safety	Understand basic lab safety procedures
6. Methods of science	Design and conduct an experiment to answer an appropriate question

B. PHYSICAL SCIENCE

7. Properties of matter	Understand properties of matter, including the classification of matter, and the difference between physical and chemical properties
8. Phases of matter	Identify types, characteristics and examples of phases of matter, and understand kinetic theory as it applies to phase change
9. Atomic structure	Understand atomic theory and the structure of the atom, including the electron, the proton and the neutron
10. Chemical and physical changes	Analyze chemical and physical changes of matter and understand the differences between them, and analyze chemical reactions, chemical equations, factors that affect reaction rates, types and characteristics of chemical bonds, electron dot diagrams, and acids, bases and salts
11. Mechanics	Understand basic principles of mechanics, including laws of motion, universal gravitation and the concept of work
12. Forms of energy	Understand types and characteristics of various types of energy, such as kinetic and potential energy, light, electricity and magnetism

13. Transfer and distribution of energy	Understand how energy is transferred by conduction, convection and radiation

C. EARTH SCIENCE

14. The universe, galaxies, stars and star systems	Understand the theory of the origin of the universe and identify the components and features of the galaxies, stars and star systems (particularly the solar system)
15. Space technology and exploration	Identify instruments and technology used in astronomy and understand their relevance to key projects of space exploration
16. Minerals and rocks	Identify types/groups of rocks and minerals, their physical characteristics (e.g., hardness, cleavage, origin) and their use
17. Weathering and erosion	Understand chemical and mechanical weathering and the erosional processes involving water, wind and glaciers
18. Earth dynamics	Understand components of Earth's crustal dynamics, including plate tectonics, mountain building, volcanic activity, folding and faulting of rocks, and components of Earth's interior dynamics, including structure, conduction and convection, and evidence of seismic activity
19. Historical geology	Identify events instrumental in the historical development of geology (e.g., principles of uniformitarianism, catastrophism), the concepts of relative and absolute time and radioactive dating and interpretive geology
20. Elements of weather and climate	Understand weather parameters (e.g., temperature, pressure, winds, humidity) and the characteristics of climate and climate modification
21. Oceanology	Understand physical, chemical, geological and biological aspects of oceanology

D. LIFE SCIENCE

22. Life processes	Understand the basic characteristics and processes that distinguish the living from the nonliving world (e.g., respiration, photosynthesis, digestion)
23. Cell biology	Demonstrate knowledge of cell theory and recognize major cell structures and their functions
24. Cell reproduction	Demonstrate knowledge of the mechanisms and significance of cell division
25. Genetics	Demonstrate knowledge of genes and chromosomes and how these are involved in the inheritance of human traits
26. Classification of living things	Show an understanding of the five-kingdom classification system and its importance in naming organisms throughout the world

27. Ecological relationships	Understand the basic ecological principles and the impact of humans on the principles (e.g., nutrient cycles, food webs, communities, pollution)
28. Human biology	Describe the anatomy of the major human body systems and explain how each operates
29. Health, nutrition and disease	Demonstrate an understanding of disease and health-related topics involving substance misuse

Appendix F
Suggested Criteria For The Selection Of Science Texts

		Good	Acceptable	Poor
I.	**Content**			
	1. Content and instructional approach are consistent with local philosophy, goals and objectives.			
	2. Content is appropriate and well balanced, i.e., for elementary schools, earth science, life science, physical science; for earth science, astronomy, geology, meteorology, oceanology.			
	3. Content is up-to-date and accurate. (Select some facts at random and check.)			
	4. Safety is stressed.			
	5. The SI metric system is used or included.			
	6. Environmental and social implications are included.			
	7. Career information is available.			
	8. Pictures, diagrams, tables and charts are appropriate for level of students.			
II.	**Authors, Support Staff and In-service**			
	1. Authors are authorities in their fields.			
	2. Authors have experience teaching the subject(s).			
	3. Editorial consultants (if used) are knowledgeable of the specific areas included.			
	4. Cooperating teachers (if used) have piloted materials.			
	5. Publisher provides in-service by authors or other consultant staff.			
III.	**Organization**			
	1. Topics are presented in a logical sequence.			
	2. Lengths of chapters, lessons or work assignments are appropriate.			

	Good	Acceptable	Poor
3. Provision is made for various levels of difficulty in an appropriate order.			
4. References, class tests and summaries are clearly represented and appropriate.			
IV. Readability			
1. Vocabulary is suitable for those who will use the text.			
2. Print is clean and well spaced.			
3. Writing style is direct and clear.			
V. Ethnic and Sex Representation			
1. Ethnic groups and the sexes are fairly represented in text, pictures and references.			
VI. Physical Features			
1. Size of book is appropriate for age of student.			
2. Books are durable – cover, binding, pages.			
3. Book is well laid out and attractive.			
4. Table of contents, index cross referencing, bibliography and resource materials are adequate.			
5. Photographs, tables and illustrations are clear, understandable and recent.			
VII. Teacher Aids			
1. Teacher's edition gives useful information about teaching techniques.			
2. Appropriate films, filmstrips and videos are listed.			
3. Test questions, problem solutions and text summaries are available and clear.			
VIII. Vendors			
1. Vendors are available to answer questions regarding in-service, initial and continuing costs.			

IX. Summary

_______ Good

_______ Acceptable

_______ Poor

X. Recommendation

_______ Purchase

_______ Hold for further discussion

_______ Reject

Appendix G

Laboratory Safety Rules Form

1. Sandals are not to be worn in the laboratory.

2. Safety glasses are to be worn at all times.

3. Long hair is a hazard and extreme care must be exercised to keep hair from contact with flame or chemicals. (Use rubber bands when necessary!)

4. It is advisable to wear clothing other than your best garb to lab. Long sleeve sweaters, blouses and shirts are not advised. Aprons will be worn when necessary.

5. Use the proper amount of chemical at all times.

6. Do not point the open mouth of a test tube at yourself or at any other person . . . In attempting to detect the odor of any substance, waft the odor toward your nose.

7. Only the lab manual, your notebook and the experiment materials are to be on the lab bench. Books and all other materials are to be left at your desk or in the bench shelf.

8. All work with chemicals is to be done over the bench top to prevent spills on the floor.

9. Keep all chemicals and reactions at a reasonable distance from your face.

10. Read all labels carefully and do not return any unused portion to the reagent container.

11. The lab tables are not for sitting or lounging. Keep off! Do not move chairs to the lab bench area or sit on the arms of the chairs.

12. Report any accident to the lab instructor immediately in order that proper first aid may be administered.

____

Name(s) of Laboratory Instructor(s)

I have read the Chemistry Laboratory Safety Rules and agree to comply with them. I understand that I will be asked to leave the laboratory should I disregard them.

________________________ ____________________

Student Signature Date

Chemistry Laboratory Safety Rules
provided by New Canaan High School

APPENDIX H
SOME FIELD TRIP SITES IN CONNECTICUT

The field trip sites listed were extracted from the three documents cited below. For additional sites, consult these documents.

Connecticut State Department of Education, *Energy Resources Inventory for Connecticut Educators.* Hartford, CT, 1978.

Connecticut Department of Environmental Protection, *Connecticut Directory of Environmental Organizations,* Hartford, CT, 1980.

Tobin, Michael F., editor. *Field Trip Guidebook, Second Edition.* Elementary and Middle School Principals Association of Connecticut. Wethersfield, CT, 1986.

(Note: For a list of planetariums in Connecticut, see Chapter 6.)

Air Quality Monitoring Stations, Air Compliance Unit, Department of Environmental Protection, Hartford, CT 06115, 566-3318

Ansonia Nature and Recreation Center, 10 Deerfield Lane, Ansonia, CT 06401, 736-9360

Audubon Center in Greenwich, 613 Riversville Road, Greenwich, CT 06830, 869-5272

Barnum Museum, 820 Main St., Bridgeport, CT 06604, 576-7320

Bartlett Arboretum, 151 Brookdale Road, Stamford, CT 06906, 322-6971

Beardsley Zoological Gardens, Noble Avenue, Bridgeport, CT 06110, 576-8082

Bradley Air Museum, Bradley International Airport, Windsor Locks, CT 06096, 623-3505

Bristol Regional Environmental Center, Wolcott Road, Bristol, CT 06010, 589-6082

Bruce Museum, Museum Drive, Greenwich, CT 06830, 869-0376

Burndy Research Library, 51 Richards Ave., Norwalk, CT 06854, 838-4444

Connecticut Audubon Society, 2325 Burr St., Fairfield, CT 06430, 259-6305 (for centers, check locally)

Connecticut 4H Farm Resource Center, Route 185, Bloomfield, CT 06002, 242-7144

Connecticut Trout Hatcheries, Burlington, CT 06013, 673-2340; Central Village, CT 06332, 564-7947; and Kensington, CT 06037, 838-5442

Connecticut Humane Society, 701 Russell Road, Newington, CT 06111, 666-3337

Connecticut Yankee Energy Information Center, Haddam Neck, CT 06438, 267-9279

Connecticut State Museum of Natural History, Storrs, CT 06268, 486-4460

Denison Homestead, Pequotsepos Nature Center, Mystic, CT 06355, 536-9248

Devil's Den, Box 1162, Weston, CT 06883, 226-4991

Dinosaur State Park, West Street, Rocky Hill, CT 06067, 529-8423

James L. Goodwin Forest Conservation Center, Potter Road and Route 6, Hampton, CT 06247, 455-9534

Hungerford Outdoor Education Center, 191 Farmington Ave., Kensington, CT 06037, 827-0964

Lutz Children's Museum, 247 South Main St., Manchester CT 06040, 643-0949

The Maritime Center at Norwalk, 10 North Water St., South Norwalk, CT 06854

Mattatuck Museum, West Main Street, Waterbury, CT 06702, 753-0381

Millstone Energy Center, 278 Main St., Niantic, CT 06357, 447-1791

Museum of Art, Science and Industry and Planetarium, 4450 Park Ave., Bridgeport, CT 06604, 372-3521

Mystic Marinelife Aquarium, 55 Coogan Blvd., Mystic, CT 06355, 536-4208

Mystic Seaport, Mystic, CT 06355, 572-0711

The Nature Center for Environmental Activities, Inc., 10 Woodside Lane, Westport, CT 06880, 227-7253

U.S. Naval Submarine Base, Groton, CT 06340, 449-3011

New Britain Youth Museum and Outdoor Center, 30 High St., New Britain, CT 06050, 225-3020

New Canaan Nature Center, 444 Oenoke Ridge, New Canaan, CT 06840, 966-9577

New Pond Farm Education Center, Umpawong Road, West Redding, CT 06896, 938-2117

Norma Terris Humane Education and Nature Center, 67 Salem Road, East Haddam, CT 06423, 434-8666

Peabody Museum, Yale University, 170 Whitney Ave., New Haven, CT 06520, 436-1710

Eliot Pratt Education Center, Inc., 163 Papermill Road, New Milford, CT 06776, 355-3137

Project Oceanology, Avery Point, Groton, CT 06340, 445-9007

Roaring Brook Nature Center, 70 Gracy Road, Canton, CT 06019, 693-0263

Science Museum of Connecticut, 950 Troutbrook Drive, West Hartford, CT 06119, 236-2961

Shepaug Eagle Observation Area (open mid-December through mid-March). Tours also available at the Shepaug Hydroelectric Station, Southbury; Northeast Utilities, P.O. Box 1337, Stamford, CT 06094, 325-4381

Sloane-Stanley Museum, Route 7, Kent, CT 06757, 927-3849

Solar Heating, Wind Generator, Computer-Controlled Heating, SNET, New Haven, CT 06506, 771-5200

The Stamford Museum and Nature Center, 39 Scofieldtown Road, Stamford, CT 06903, 322-1646

Stevenson Hydroelectric Station in Monroe, Northeast Utilities, P.O. Box 1337, Stamford, CT 06094, 325-4381

Talcott Mountain Science Center, Montevideo Road, Avon, CT 06001, 677-8571

The Thames Science Center, Gallows Lane, New London, CT 06320, 442-0391

University of Connecticut Museum of Natural History, 233 Glenbrook Road, Storrs, CT 06268, 486-4460

Westmoor Park, 119 Flagg Road., West Hartford, CT 06117, 232-1134

West Rock Nature Recreation Center, Box 2969, New Haven, CT 06515, 787-8010

White Memorial Conservation Center, Box 368, Litchfield, CT 06759, 576-0015

Appendix I
State And National Events For Science Students

Connecticut Science Fair, Connecticut Science Fair Association, Inc., P.O. Box 31238, Hartford, CT 06114. A statewide science and engineering fair, the Connecticut Science Fair is offered free and brings together 700 students in Grades 7-12 with strong interest in science and engineering for a week-long fair. Over 300 awards are given. The four top winners receive an all-expense-paid opportunity to compete in the International Science and Engineering Fair.

Junior Science and Humanities Symposium, Chemistry Department, University of Connecticut, Storrs, CT 06268. The symposium is intended to recognize students in Grades 11 and 12 who have demonstrated intellectual achievement and promise. It is open to about 150 students and 50 teachers. Lectures, demonstrations and discussions with prominent scientists are featured. Visits are made to significant sites of scientific and technological activity. An important aspect of the program is the individual research papers presented by students.

National Youth Science Camp, State Department of Education, P.O. Box 2219, Hartford, CT 06145. Application forms are sent to all public and private high schools in Connecticut. Two high-achieving Grade 12 students are selected by a committee of the Connecticut Science Teachers Association. The winners represent Connecticut at a four-week summer science camp near Green Bank, West Virginia. They, along with student representatives from the other states, meet with scientists, U.S. senators and representatives and other government officials; visit science facilities; and engage in other camp activities. All travel, lodging and meal expenses are covered by the camp.

Westinghouse Science Talent Search, Science Service, 1719 N Street, NW, Washington, DC 20036. Applications are sent to high schools. High school seniors with strong research ability in science and engineering are encouraged to apply. Three hundred students from across the nation are selected for the honors group. All members are recommended for admission and scholarship awards to colleges and universities in the nation. Forty members from the honors group are designated top winners. This group of students is invited to Washington, DC, for a five-day institute usually held in late February. During this period they are judged for scholarships and awards in various dollar amounts.

United States Department of Energy Honors Program, Connecticut State Department of Education, P.O. Box 2219, Hartford, CT 06145. All-expenses-paid trips to various laboratories run by the U.S. Department of Energy. One student from Connecticut is selected for each program. Presently there are seven. Each student spends time at a laboratory working with a scientist on a particular project. The selections of the students attending the program are made by a committee of representatives from the Connecticut Science Teachers Association.

JETS-TEAM Connecticut Competition, University of New Haven, 300 Orange Ave., West Haven, CT 06576. Each interested school enters a team of six students. The teams are tested in the areas of biology, chemistry, computer fundamentals, English, mathematics and physics. Each student on a team takes two exams and each school must have two students take each test. Awards are presented and winners move on to a national event.

Science Horizons, Downtown Campus, Western Connecticut State University, Danbury, CT 06810. This series of events includes a science symposium for students in Grades 9-12, a science fair for students in Grades 7-12, and a community forum in which leaders in the field of science make presentations and lead discussions on particular topics.

Appendix J

Connecticut Policy On Academic Freedom And Public Education

Academic freedom is the freedom to teach and to learn. In defending the freedom to teach and to learn, we affirm the democratic process itself. American public education is the source of much that is essential to our democratic heritage. No other single institution has so significantly sustained our national diversity, nor helped voice our shared hopes for an open and tolerant society. Academic freedom is among the strengths of American public education. Attempts to deny the freedom to teach and to learn are, therefore, incompatible with the goals of excellence and equity in the life of our public schools.

With freedom comes responsibility. With rights come obligations. Accordingly, academic freedom in our public schools is subject to certain limitations. Therefore, the STATE BOARD OF EDUCATION affirms that:

Academic freedom in our public schools is properly defined within the context of law and the constraints of mutual respect among individuals. Public schools represent a public trust. They exist to prepare our children to become partners in a society of self-governing citizens. Therefore, access to ideas and opportunities to consider the broad range of questions and experiences which constitute the proper preparation for a life of responsible citizenship must not be defined by the interests of any single viewpoint. Teachers, school administrators, librarians, and school media specialists must be free to select instructional and research materials appropriate to the maturity level of their students. This freedom is itself subject to the reasonable restrictions mandated by law to school officials and administrators. At the same time, local school officials must demonstrate substantial or legitimate public interest in order to justify censorship or other proposed restrictions upon teaching and learning. Similarly, local boards of education cannot establish criteria for the selection of library books based solely on the personal, social or political beliefs of school board members. While students must be free to voice their opinions in the context of a free inquiry after truth and respect for their fellow students and school personnel, student expression which threatens to interfere substantially with the school's function is not warranted by academic freedom. Students must be mindful that their rights are neither absolute nor unlimited. Part of responsible citizenship is coming to accept the consequences of the freedoms to which one is entitled by law and tradition. Similarly, parents have the right to affect their own children's education, but this right must be balanced against the right other parents' children have to a suitable range of educational experiences. Throughout, the tenets of academic freedom seek to encourage a spirit of reasoned community participation in the life and practices of our public schools.

Since teaching and learning are among the missions of our public schools, the STATE BOARD OF EDUCATION affirms the distinction between teaching and indoctrination. Schools should teach students how to think, not what to think. To study an idea is not necessarily to endorse an idea. Public school classrooms are forums for inquiry, not arenas for the promulgation of particular viewpoints. While communities have the right to exercise supervision over their own public school practices and programs, their participation in the educational life of their schools should respect the constitutional and intellectual rights guaranteed school personnel and students by American law and tradition.

Accordingly, the STATE BOARD OF EDUCATION, in order to encourage improved educational practices, recommends that local school boards adopt policies and procedures to receive, review, and take action upon requests that question public school practices and programs. Community members should be encouraged, and made aware of their rights to voice their opinions about school practices and programs in an appropriate administrative forum. The STATE BOARD OF EDUCATION further recommends that local school boards take steps to encourage informed community participation in the shared work of sustaining and improving our public schools.

Finally, the STATE BOARD OF EDUCATION affirms that community members and school personnel should acknowledge together that the purpose of public education is the pursuit of knowledge and the preparation of our children for responsible citizenship in a society that respects differences and shared freedom.

Adopted by the Connecticut State Board of Education
September 9, 1981

Appendix K
Regional Educational Service Centers

ACES	Area Cooperative Educational Services 205 Skiff Street Hamden, CT 06517 248-9119
CES	Cooperative Educational Services 785 Unquowa Road Fairfield, CT 06430 255-7585
CREC	Capitol Region Education Council L.P. Wilson Community Center 599 Matianuck Avenue Windsor, CT 06095 688-7333
EASTCONN	Eastern Connecticut Regional Educational Service Center 376 Hartford Turnpike North Windham, CT 06256 455-0707
PROJECT LEARN	Project Long Range Educational Assistance for Regional Needs P.O. Box 220 East Lyme, CT 06333 739-6971
RESCUE	Regional Educational Services Concepts Through Unified Effort 355 Goshen Road Litchfield, CT 06759 567-0863 and 301 Main Street Danbury, CT 06810 791-1904

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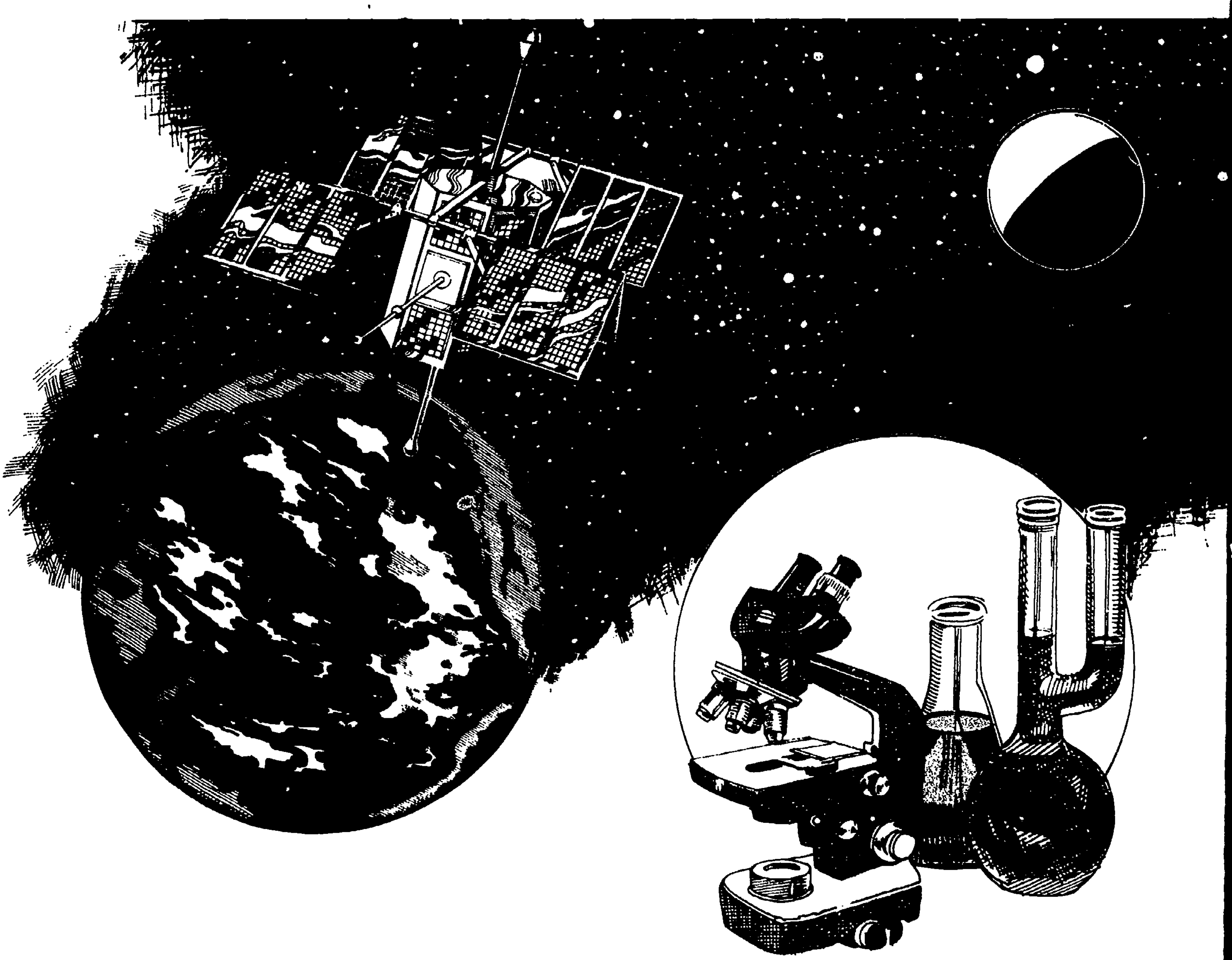

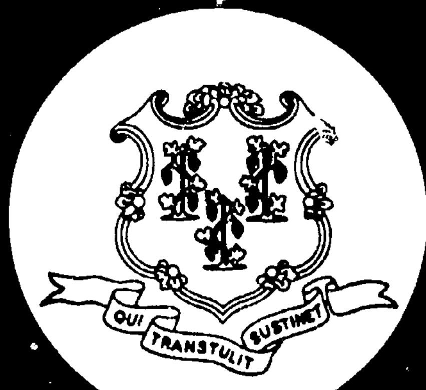
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